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A Microcomputer Pollution Model for Civilian Airports and Air Force Bases
MODEL APPLICATION AND BACKGROUND

US Department of Transportation
Federal Aviation Administration
Office of Environment and Energy
Washington, D.C. 20591

United States Air Force
Engineering Services Center
Tyndall Air Force Base, Florida 32403

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15. Supplementary Notes

16. Abstract

This is one of three reports describing the Emissions and Dispersion Modeling System (EDMS). All reports use the same main title--A MICROCOMPUTER MODEL FOR CIVILIAN AIRPORTS AND AIR FORCE BASES--but different subtitles. The subtitles are:

(1) USER'S GUIDE - ISSUE 2 ----------- (FAA-EE-88-3/ESL-TR-88-54)
(2) MODEL DESCRIPTION ---------------- (FAA-EE-88-4/ESL-TR-88-53)
(3) MODEL APPLICATION AND BACKGROUND - (FAA-EE-88-5/ESL-TR-88-55)

The first and second reports above describe the EDMS model and provide instructions for its use. This is the third report. It consists of an accumulation of five key documents describing the development and use of the EDMS model. One of the documents shows the application of EDMS to the assessment of air pollution at Stapleton International Airport.

This report is prepared in accordance with discussions with the EPA and requirements outlined in the March 27, 1980 Federal Register for submitting air quality models to the EPA.

17. Key Words	18. Distribution Statement
POLLUTION, AIR POLLUTION, DISPERSION	THIS DOCUMENT IS AVAILABLE TO THE PUBLIC

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INTRODUCTION

Key reports, summarizing the Emissions and Dispersion Modeling System (EDMS), have been assembled in order to describe the development and use of the EDMS model. This document is the repository for these key reports.

These reports were prepared in accordance with discussions with the Environmental Protection Agency (EPA) and instructions provided in the Federal Register (March 27, 1980) for the submission of air quality models to the EPA for consideration as Guideline models.

MODEL DEVELOPMENT AND USE - ITS CHRONOLOGY AND REPORTS

The need for an effective model to evaluate pollution from aircraft was first identified during the analysis of Concorde emissions at Dulles International Airport (IAD) in 1976. During this analysis, it was noticed that existing models can not accommodate detailed changes in power setting, speed, and ground track as aircraft enter different operational modes at an airport.

The summary report of the analysis of Concorde (and other aircraft) emissions at IAD is located in Appendix A. It should provide insight into model development problems caused by the unique operational characteristics of aircraft.

The need for a flexible, easy-to-use model to analyze aircraft emissions became more apparent in the late 1970's when both the Environmental Protection Agency (EPA) and the International Civil Aviation Organization (ICAO) started to develop the rationale for the imminent engine emission standards. The basic question to be answered was, "How significant a source of pollution are aircraft?"

To help answer, this question the Federal Aviation Administration (FAA), the United States Air Force (USAF), and the EPA established an air quality study to quantify the impact of aircraft emissions on air quality at airfields. During this study, a simple model was developed to help evaluate monitoring data. However, this model was quite cumbersome to use since all calculations had to be made by hand. A summary of this air quality study, which was completed in 1980, is included in Appendix B.

The nonavailability of small yet powerful computers has impeded the development of a simple, flexible model. However, in the late 1970's, computers having this capability were starting to become available. One such computer, the Hewlett Packard 97 (HP-97), was then used to model emissions from an aircraft that would be accelerating down a runway during takeoff. The resulting model is described in Appendix C.

With the introduction of personal computers in the early 1980's, the HP-97 code was reprogrammed for an Apple II+ microcomputer. This approach led to the original GIMM--Graphical Input Microcomputer Model which was completed in 1982. Because it employed the more powerful Apple computer, GIMM could be

Realizing the effectiveness of GIMM in meeting both FAA and USAF needs, the FAA and the USAF issued a memorandum of understanding (MOU) to formally blend the efforts of both agencies. This MOU documented the need for a single FAA/USAF microcomputer model to evaluate air quality at both airports and airbases. This model--the Emissions and Dispersion Modeling System (EDMS)--incorporates the emissions and dispersion algorithms of the original GIMM that have been speeded up and processed through a commercial data base. EDMS was completed in 1985, and its code and User's Guide were released to the general public in December 1985 as report FAA-EE-85-4/ESL-TR-85-41.

Since that time, major modifications have been made to the original EDMS to enhance its usability and incorporate an integral dispersion model into its code. A prototype of this expanded model was completed in 1986 and was used to analyze air quality at Stapleton International Airport in conjunction with the building of a new runway for that airport. The summary report for this application of EDMS is contained in Appendix E.

Since 1986, the prototype EDMS has been incorporated into the main EDMS system, and the final model has been submitted to the EPA as an agenda item for the Fourth Conference on Air Quality Modeling.

APPENDIX A

MONITORING CONCORDE EMISSIONS

MONITORING CONCORDE EMISSIONS

Howard Segal

Federal Aviation Administration

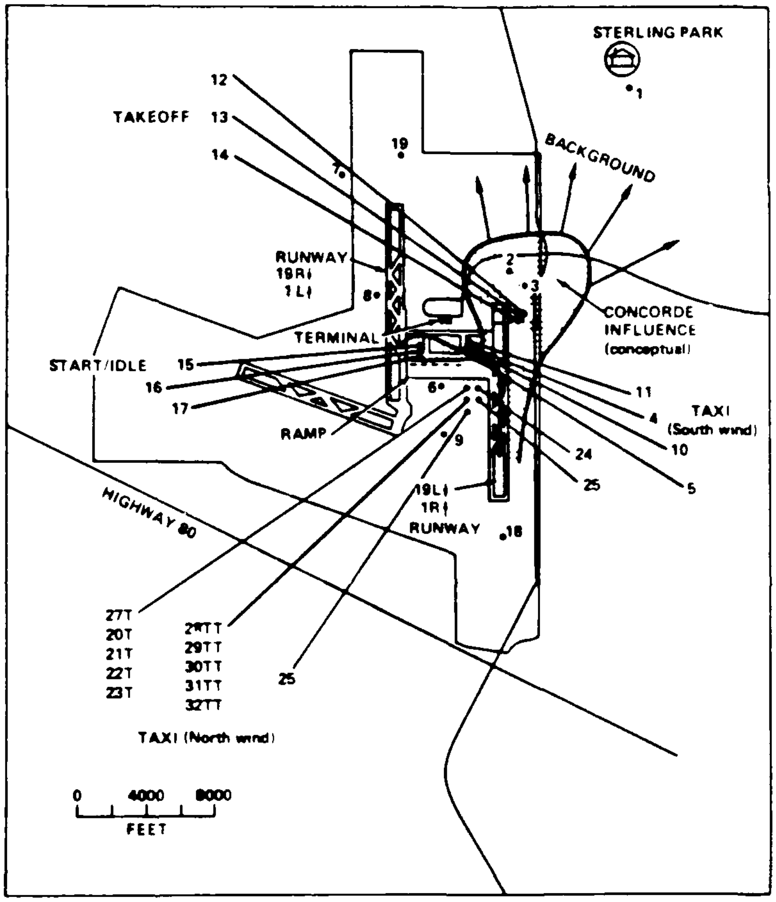

Figure 1. Pollution monitoring sites

On February 4, 1976, the Secretary of Transportation ordered the FAA to monitor emissions (and noise) at Dulles International Airport. To comply with this order, it was necessary to measure the ambient pollution levels (background) in and around Dulles Airport and to trace the dispersion of emissions from a single Concorde aircraft. While the more conventional background measurements could be easily performed, there was no known case where the vertical and horizontal profile of the emission plume from a single aircraft had been identified. A mobile monitoring program was, therefore, initiated to determine if the emission plume of a taxiing or taking off aircraft could be detected. Special instruments were required to measure the discrete, non-steady state nature of the dispersion of the aircraft plume. The final measurement system, which consisted of continuously recording instruments coupled with high-speed chart recorders, successfully detected emissions from a single aircraft. Long term measure-

On February 4, 1976, the Secretary of Transportation ordered the FAA to measure the noise and low-altitude emissions of the Concorde aircraft in connection with a 16 month trial period for that aircraft.[1] This paper describes the low-altitude emissions portion of the program, which is being performed at Dulles International Airport.

Measurements began on May 25, 1976, the date of the first Concorde departure from Dulles airport. Results

Mr Segal is Project Officer, Concorde Emission Monitoring Office of

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Table I. Concorde monitoring schedule.

	1976											1977								
	FEB	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	SEP
Secretary's Concorde decision	Δ																			
First Concorde departure (monitoring starts)					Δ															
Background monitoring					—	—	—	—												
Taxi monitoring					—	—	—	—												
Takeoff monitoring									—	—	—	—	—	—	—					
Tower monitoring (one tower)										—										
Tower monitoring (two tower)													—							
Data analysis and reporting														—	—	—	—	—		
Final Concorde report																			Δ	
Monthly report*					Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ			
Six-month summary report*													Δ							

*Available from the Federal Aviation Administration
Office of Environmental Quality
800 Independence Avenue, S.W.
Washington, D.C. 20591

from these measurements are described through Feb. 1977 (the cutoff date for preparation of this paper). The program schedule is listed in Table I.

In order to comply with the Secretary's order to monitor Concorde emissions, it was necessary to measure both the change in ambient air quality caused by the operation of a single Concorde aircraft (single event), and the pollution background on and off the airport. While the more conventional background measurements could be easily performed, there was no known case where the vertical and horizontal profile of a single aircraft's emission plume had been identified. Past studies[2-4] had been unsuccessful in such identification, because they were carried out in high-background congested airports where circuitous taxiing in and around complex terminal areas was required.

Background levels are low at Dulles Airport, where most aircraft use only one isolated ramp. Aircraft generally do not approach the terminal where pollution from numerous sources may intermingle. A mobile monitoring program was, therefore, started to determine if the emission plume from a taxiing aircraft could be detected. Results of this program showed that continuously recording instruments coupled with high-speed recorders could detect emissions from a single aircraft. Long term measurements of background and single event pollution were then begun.

Objective

The principal objective of this program was to measure the effect of Concorde emissions on populated areas at or near Dulles airport. Air quality was determined at two main populated areas, namely, the airport itself and the Sterling Park Community. These locations are shown in Figure 1. The impact of the airport (and Concorde) emissions on the air quality at Sterling Park was determined by measuring the pollution background upwind and downwind of the airport. The impact of Concorde emissions on the airport itself was determined by measuring the change in pollutant concentration levels caused by emissions from a single aircraft as it started, taxied, and took off. The distance from the taxiing aircraft source at which these emissions blend into the background determined the effect of Concorde emissions on the terminal area. Single event measurements were

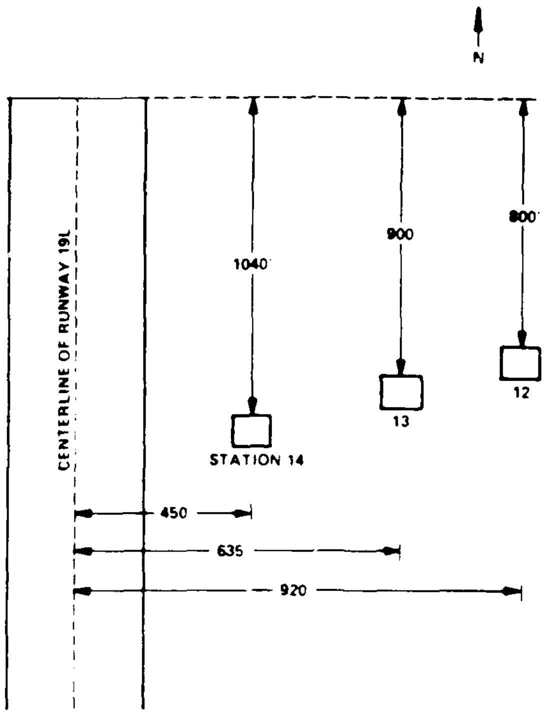


Figure 3. Takeoff station locations

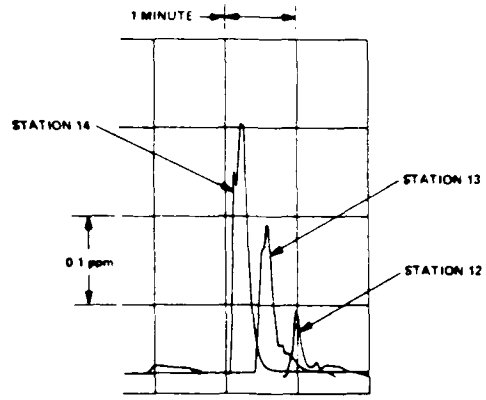


Figure 4. Characteristic plot of NO_x concentration during takeoff

also made to determine engine emission rates for comparison with those listed in the Concorde environmental impact statement.⁵ A model is being developed from these measurements. The Concorde influence area shown in Figure 1 will be determined from this model.

Approach

Six a · quality stations and two vertical towers were employed for both background and single event measurements. Background measurements were performed at two main stations; one measuring the airport background and the other measuring the community background. All major pollutants (carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO), nitrogen dioxide (NO_2), ozone (O_3) and particles), as well as wind direction and speed were measured continuously at these locations. A third station initially set up to monitor takeoff emissions was found to be useful for background measurements. This station recorded CO, NO, and wind speed and direction.

Single event measurements were used to define the Concorde influence area and to provide the detailed data for background pollution analysis. Measurements were made at three stations and on two towers. The measurement

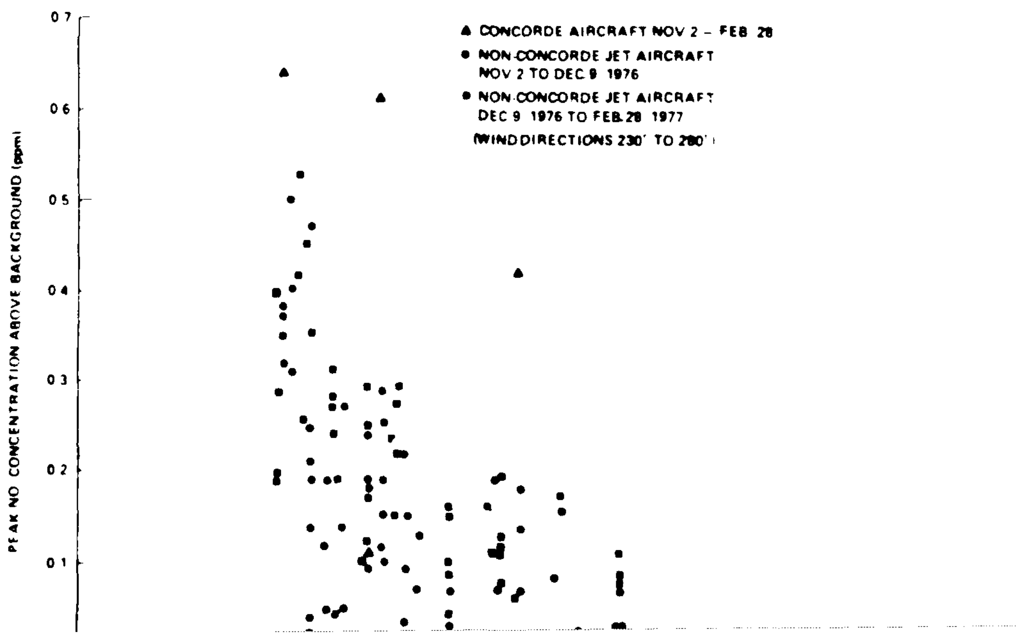
for taxi and start/idle emissions. NO_x was the tracer for takeoff emissions. Continuously recording instruments coupled with high-speed chart recorders were employed to measure plume passage, which usually lasted less than two

minutes. Vertical pollution measurements were made at five elevations on two vertical towers.

Site Selection and Instrumentation

Site selection considerations were: 1. probable success in detecting an event; 2. freedom from spurious emissions; 3. frequency at which aircraft passed the monitoring sites; 4. available power; 5. wind direction; 6. noninterference with other airport c· · ·ations.

Six instrumented trailers plus mobile equipment were moved at different



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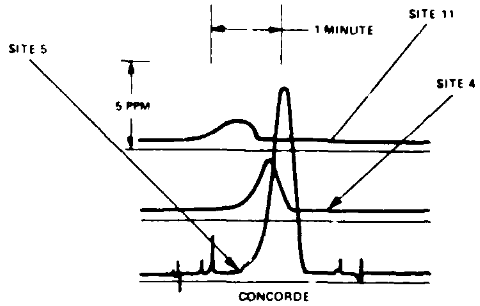


Figure 6. Characteristic plot of CO concentration during taxi

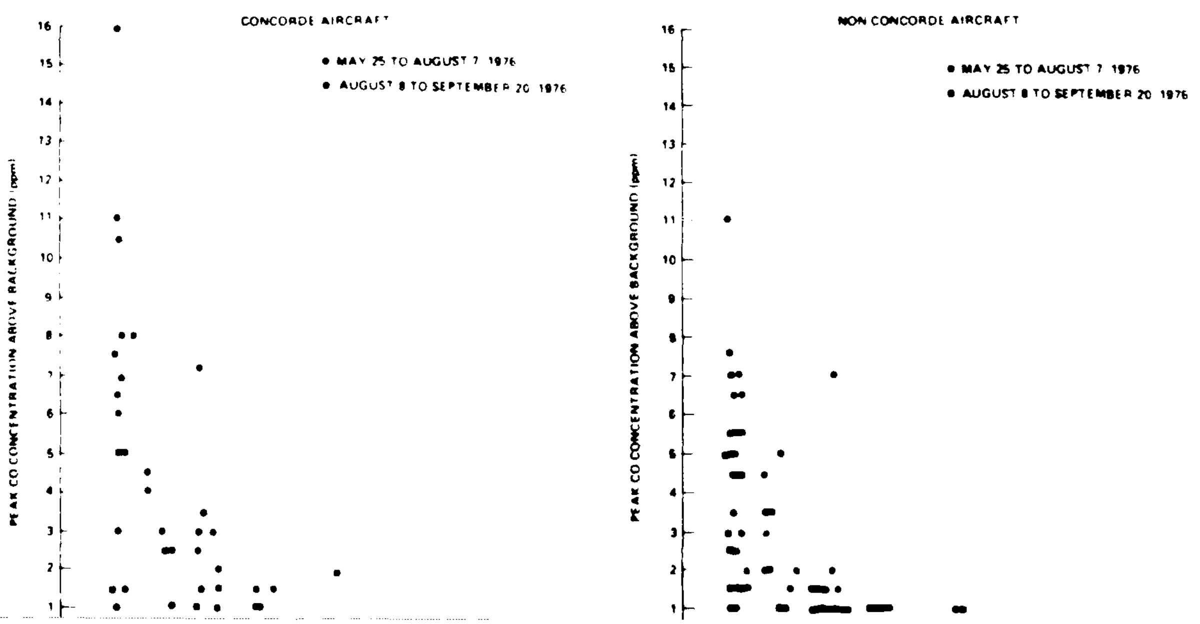
times to the 32 sites shown in Figure 1 for pollution assessment purposes. Location, instrumentation, measurement purpose, and operational dates are tabulated in Table II. Equipment at the following sites monitored the operational modes and weather parameters listed:

	Site Number
Taxi (surface)	4, 5, 10, 11, 24, 25, 26
Engine Start/Idle	15, 16, 17
Takeoff (precursor)	2, 3
Takeoff	12, 13, 14
Taxi (plume rise - single tower)	20T, 21T, 22T, 23T
Taxi (plume rise double tower)	27T, 20T, 21T, 22T, 23T, 28TT 29TT, 30TT, 31TT, 32TT
Background	1, 6
Approach	19
Climb out	18
Meteorological (wind speed and direction)	8, 9, 6, 10, 12, 24
Meteorological (vertical temperature)	7

Instrument selection was influenced by the unique nature of the aircraft pollution source. Most non-aircraft sources are steady state in nature and change little over long periods of time. These sources are amenable to long sampling time instrumentation. The emission plume from a moving aircraft, however, is a non-steady state puff and undergoes a wide concentration excursion as the emission plume passes over the downwind monitoring station. This passage which usually takes less than two minutes requires continuously recording instruments and high-speed chart recorders to record the rapid passage of this event. This equipment was, therefore, used to record the short-duration passage of the Concorde emission plume.

Equipment for background and single event monitoring are listed below:

- Carbon Monoxide
  - Intertech Co.—URAS2—NDIR
  - Energetic Sciences Inc., Ecolyzer 2600E
- Nitric Oxide/Nitrogen Dioxide
  - Thermo Electron Co. 14B Analyser
  - Monitor Labs Inc., 8500 Calibrator
- Total Suspended Particulates
  - BGI-IIA Hi Volume Sampler
  - BGI-HCII Standard Calibrator
- Total Hydrocarbons
  - Beckman Instruments Inc.—Model 400
- Non-Methane Hydrocarbons
  - Beckman Instruments Inc.—Model 6800
- Ozone
  - McMillan Electronics Co.—1100 Analyser,
  - 1020 Ozone Generator
- Wind Speed & Direction
  - Climet Instruments Co.—011-1
  - Wind Speed Transmitter, 012-10
  - Wind Direction Transmitter, 060-10 Transmitter



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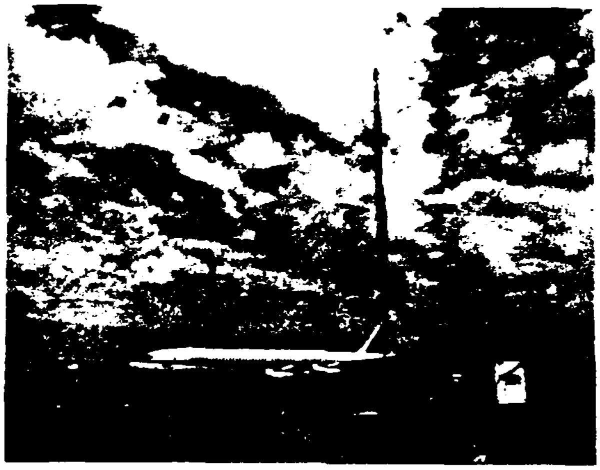

Figure 8. Tower installation

Temperature
Climet Instrument Co.--015-3
Temperature Sensor, 060-10
Translator

A major consideration in site selection was the traffic pattern being used at the airport. Most commercial aircraft do not operate in the vicinity of the terminal, but rather, position themselves at the jet ramp which is located 2300 ft south of the terminal. Airplanes move around this ramp in a clockwise direction. For south wind operations, which are predominant during the summer months, the airplanes usually proceed from the ramp to takeoff runway 19 left, which assures the shortest possible taxi distance. For north wind operations, airplanes proceed from the ramp to runway 1-left. Considering this traffic pattern, the most effective location for taxi monitoring during the summer months is at the turf area just off the northeastern edge of the taxi ramp (Figure 2). Monitoring started at two locations (4 and 5). A third location was added first at site 10 and then at site 11 to provide the three points needed to determine emission dispersion. As the wind shifted to the north in the winter months, the three taxi monitoring stations were moved to the other side of the taxi ramp. Measurements to record the vertical pollution profile were performed at this location. Power for all taxi monitoring was provided by an FAA 15KW Diesel electric generator.

Location of the takeoff monitoring sites (12, 13 and 14) was determined through analysis of precursor measurements taken at sites 2 and 3. Sites 12, 13 [illegible] spot-checked at Sites 15, 16, and 17. Monitoring for queuing was initially planned but then dropped because queuing did not occur at the time of Concorde departure.

Results

Between May 1976, and Feb. 1977, the Concorde monitoring system recorded the pollution background on and off the airport, and emissions from aircraft single events during engine start-idle, taxi, and takeoff. Major emphasis has been on monitoring the pollution background and the emission plume transport from a taxiing or taking off aircraft.

Background Measurements

All major pollutants were measured at Sites 1 and 6. The background was measured to relate air quality on and off the airport and to compare pollution in the vicinity of the airport with the national ambient air quality standards. These data are reported in References 6-9 and the analysis will be described in the final Concorde monitoring report.

Takeoff Measurements

Emissions at Sites 12, 13, and 14 were measured from Nov. 1976 to Feb. 1977. Site locations are shown in Figure 3 and measurements were taken at the three downwind locations. A characteristic trace of the pollution time history is shown in Figure 4. Cumulative peak concentrations at different distances [illegible]

Taxi Measurements (Surface)

Emissions at sites 4, 5 and 11 were measured from May to Sept. 1976. A characteristic plot of air quality during Concorde plume passage is shown in Figure 6. Cumulative plots of Concorde and non-Concorde emissions are shown in Figure 7. These data support the following trends.

1. The average peak CO concentration for Concorde is 1.7 times higher than the average concentration of the other aircraft monitored at a location 200 ft downwind from the taxiing aircraft.
2. Emissions from Concorde (and other airplanes) disperse to background levels before they reach the terminal (2300 ft from the ramp taxiway).
3. The contribution of one taxiing Concorde to the hourly average CO concentration of all other sources is less than 0.1 parts per million (ppm) at locations as close as 200 ft from the center line of the taxiway.

Taxi Measurements—(Tower)

Two tower tests were performed: a single-tower test to determine vertical plume characteristics and a double-tower test to determine change in plume characteristics between the two towers.

The single-tower test was performed on Nov. 1 through the 15th, using a 58 ft tower with four vertical pollution intake positions. The second test was started on Feb. 20, 1977, for a planned week time period and consisted of the first 58 [illegible]

Table II. Characteristics of monitoring sites.

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Site #	Approximate Location	Measurement	Function	Operational Status
1	Sterling Park	CO, NO and NO_2, total HC, particles, O_3, methane, WD/WS*	Monitor air quality change in the community during Concorde operation	June-Sept. 1976
2	2000 ft north and 125 ft east of the east runway	CO, NO_x, WD/WS*	Measure takeoff emissions as precursor to defining locations for 3 station takeoff grouping. Background station	May-Aug. 1976
3	1100 ft north and 1000 ft east of the east runway	NO_x	Measure takeoff emissions as precursor to defining locations for 3 station takeoff grouping.	May-Aug. 1976
4	Taxi grouping: 480 ft. north of the jet ramp taxiway & 200 ft east of the mobile lounge ramp	CO, WD/WS*	Trace emission propagation during taxi (single event)	May-Sept. 1976
5	Taxi Grouping: 190 ft north of the jet ramp taxiway and 200 ft east of the mobile lounge ramp	CO	Same as 4	May-Sept. 1976
6	South edge of the main ramp [illegible] the [illegible] access road	CO, NO and NO_2, total HC, particles, O_3, WD/WD*	Monitoring pollution background of the airport	May-Sept. 1976
7	Northwest of airport (NOAA owned)	Vertical temp.	Measure inversion base	Continuous
8	West of the west runway (NOAA owned)	WD/WS* [illegible] recorder	Monitor wind speed and direction	Continuous
9	3000 ft [illegible] of Site 6 (NOAA owned)	WD/WS*	Monitor wind speed and direction	Continuous
10	Taxi grouping, midway between Site 4 and 5	CO	Same as 4	June-July 1976
11	Taxi Grouping: 200 ft north of Site 4	CO	Same as 4	July-Sept. 1976
12	Takeoff Grouping: 28[illegible] ft east and 100[illegible] north of Site 1[illegible]	CO, NO and NO_2, total HC, O_3, WD/WS*	Trace emission propagation during takeoff (single event)	Oct. '76-March 1977
13	Takeoff Grouping: 185 ft east and	CO, NO_x	Same as 12	Sept. '76-March 1977

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Table II. Characteristics of monitoring sites.

Site #	Approximate Location	Measurement	Function	Operational Status
15 16 17	Start/idle Grouping north of the west and of the jet ramp taxiway	CO, WD/WS*, (at one site)	Trace emission propagation during engine start/idle (single event)	Spot check
18	South of the east runway	NO_x	Monitor takeoff emissions	Spot check
19	North of the west runway	NO_x	Monitor landing emissions	Spot check
20T	South edge of main ramp 1700 ft** west of Runway 19L, 56 ft elevation on tower		Air intake position (tower)	Nov. 1976
21T	41 ft elevation on tower		Same as 20T	Nov. 1976
22T	26 ft elevation on tower		Same as 20T	Nov. 1976
23T	14-ft elevation on tower		Same as 20T	Nov. 1976
24	South edge of main ramp† 1665 ft** west of Runway 19L	CO, WS/WD*	Tower measurements	Nov. 1976
25	1665 ft** west of Runway 19L 164 ft south of Site 24	CO	Tower measurements	Nov. 1976
26	1700 ft** west of Runway 19L 164 ft south of Site 25		Air intake position (Surface)	Nov. 1976
27T	Same as 20T 76 ft elevation on tower		Same as 20T	Feb.-March 1977
28TT	164 ft south of 20T, 76 ft elevation on tower		Same as 20T	Feb.-March 1977
29TT	Same as 28TT 56 ft elevation on tower		Same as 20T	Feb.-March 1977
30TT	41 ft elevation on tower		Same as 20T	Feb.-March 1977
31TT	26 ft elevation on tower		Same as 20T	Feb.-March 1977
32TT	14 ft elevation on tower		Same as 20T	Feb.-March 1977

*WD/WS - wind direction/wind speed

**South end Centerline

†215 ft south of south jet ramp centerline

All dimensions are measured to centerline of ramp or taxiway unless otherwise noted

sampling pump which transmitted the single-tower tests are listed in Ref. 10 emissions will be reported after the 12 reduce to levels undetectable from the background within 2000 ft of the taxiing aircraft. Concorde (and other aircraft) single-event emissions contribute less than 0.1 ppm of CO to ambient air concentrations at locations as close as 200 ft from a taxiing aircraft, when averaged over a one hour time period.

Tower measurements show that the hot emission plume tends to lie close to the ground and does not rise significantly at monitoring station locations. Specific relationships between surface and higher-level concentrations will be evaluated later on in the program.

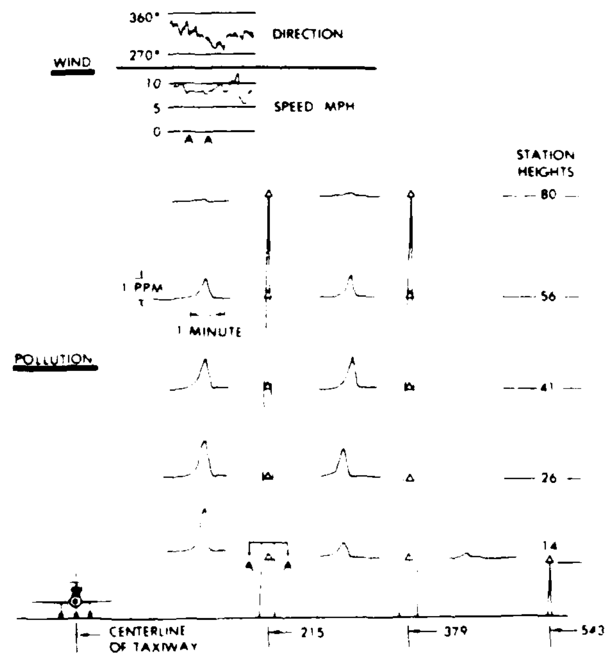

Figure 9. *Characteristic strip chart plots of wind and pollution (tower demonstration)*

A simple model is being developed from the measurement data. The model describes the downwind concentrations of the emissions from a single aircraft passage and sums up the emission contributions of a number of single aircraft passages over longer time periods.

Acknowledgments

are the result of the dedicated efforts and support of a number of persons within the government and private industry.

David Chang, Don Muldoon, and Thomas Thompson from Environmental Research and Technology, Inc., provided, installed and maintained all instrumentation and reduced the data.

Major Peter Crowley and Captain Dennis Naugle of the Air Force Civil Engineering Center encouraged the tower test and provided funding for its performance.

David Shearer and D. Bruce Turner of the EPA, and Gordon Banerian of the NASA, provided the technical sounding board to insure a meaningful program.

John Curran and Melvin Watine of the FAA Eastern Region, secured and delivered the Diesel Electric generator and electrical equipment in the short time between the Secretary's Concorde decision and the start of monitoring.

tional Airports arranged for and performed all ground support to the monitoring operation, including operation and maintenance of the Diesel Electric Generator. Their prompt response to monitoring problems in the field was a key element in the success of this program.

Robert Logan of the FAA Eastern Region, integrated the monitoring operation into air traffic operations at the airport.

Robert Chen of the FAA Office of Environmental Quality, was intimately involved in program technical review and Concorde monthly report preparation.

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APPENDIX B

THE INFLUENCE OF AIRCRAFT OPERATIONS ON AIR QUALITY AIRPORTS

the influence of aircraft operations on air quality at airports

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Robert Yamartino
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Emission standards for aircraft engines were promulgated in 1973 after it was determined that these engines were significant sources of pollution around airports. Since that time, new information has become available on the modeling and monitoring of aircraft emissions and in March 1978 the Environmental Protection Agency (EPA) announced its intention to amend the 1973 standards. Included in this announcement was the establishment of a joint FAA/EPA air quality study which included the reassessment of the impact of aircraft emissions on air quality around airports. This paper presents the results of this study which includes the assessment of air quality at five commercial and one general aviation airport. Also presented are the preliminary results of research performed since the completion of the study. It is concluded that aircraft emissions have a smaller impact on air quality than had been estimated in studies that were performed prior to the promulgation of the aircraft engine emission standards in 1973.

The 1970 amendments to the Clean Air Act[1] directed the Environmental Protection Agency (EPA) to establish emission standards for aircraft and aircraft engines, if such emissions are judged to cause or are likely to cause or contribute to air pollution which endangers public health or welfare. The 1970 amendments also directed the EPA to conduct a study of the extent to which aircraft emissions affect air quality in Air Quality Control Regions (AQCR) throughout the United States. Based upon information available in the early 1970s,

Since that time, major advances have been made in the techniques for monitoring and modeling aircraft emissions. On March 24, 1978, a Notice of Proposed Rulemaking (NPRM) was published in the *Federal Register* to announce the intention of the EPA to amend the 1973 engine emission standards. Included in the NPRM was the establishment of a joint Federal Aviation Administration (FAA)/EPA air quality study to relate aircraft emissions to ambient air quality.

In setting up this air quality study, it was decided first to review data generated both before and after the promulgation of the engine emission standards to determine the completeness of these data in establishing an air quality basis for the engine emission standards. During this review, it was found that the magnitude of the initial pollutant dilution caused by exhaust gas heat and turbulence was only first measured in 1976. Therefore, modeling results prior to 1976 could be subject to substantial error. New pollution monitoring programs were then initiated to get additional plume-related information. The resulting monitoring analysis programs summarized in this paper involved the coordinated efforts of the FAA, the EPA, and the Air Force, Argonne National Laboratory (ANL) and Environmental Research and Technology, Incorporated (ERT). A detailed technical report has also been issued.[2]

Approach

The need for engine emission control is determined through the evaluation of economic, technological, and air quality data. This paper addresses the evaluation of air quality data through the modeling and monitoring of aircraft emissions at a number of airports. Essential to this evaluation is the development of good air quality data for model validation. But it was not until 1976 that the emission plume from aircraft was successfully isolated from other airport sources. This plume of the Concorde measurement program,[3] permitted the vertical profile and trajectory of the aircraft emission plume to be quantified for the first time. A typical event is depicted in Figure 1 and an ensemble of such events, spanning a wide variety of meteorological conditions and aircraft types enabled development of a plume rise equation for taxiing aircraft exhaust plumes.

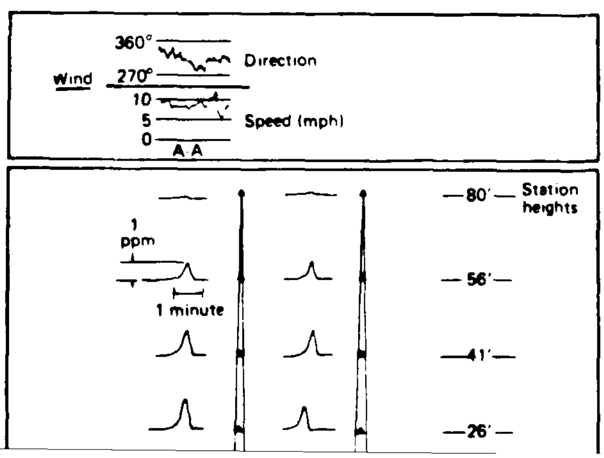
The pollution assessment strategy, which is described in Figure 2, was directed toward quantifying the initial size and height of the emission plume from individual aircraft prior to the dispersion of this plume in the ambient air. This information was incorporated into the Airport Vicinity Air Pollution (AVAP) model[4] which was then used to calculate pollutant concentrations at the three large airports that were evaluated in conjunction with the 1973 engine emission standards.

Monitoring and modeling program characteristics at four airports are listed in Table I. Modeling results made use of the following "worst case" conditions in an attempt to reflect the implied meteorological and activity conditions of the NAAQS.

Averaging time—1 hr
Pasquill/Gifford stability class—*E*
Wind speed—1 m/sec
Aircraft activity—Peak levels
Receptor location—750 m downwind from the runway/taxiway. (This is the characteristic distance at which the general public might first be exposed to pollution from aircraft.)

Pollutant Considerations

Four pollutants emitted by aircraft, CO, HC, nitrogen oxide (NO) and nitrogen dioxide (NO_2) (NO + NO_2 is referred to as NO_x) have been judged in the past to be significant. Only NO_2 and CO are considered in detail in this paper because their concentrations can be directly compared to an appropriate NAAQS. The impact of aircraft HC and NO emissions on oxidant levels was not addressed in this study because of the state-of-the-art limitations in the modeling and related monitoring of photochemical reactions, especially when the reactive species are not well defined. The rationale for possibly controlling these precursor pollutants must arise from other considerations.



B-3

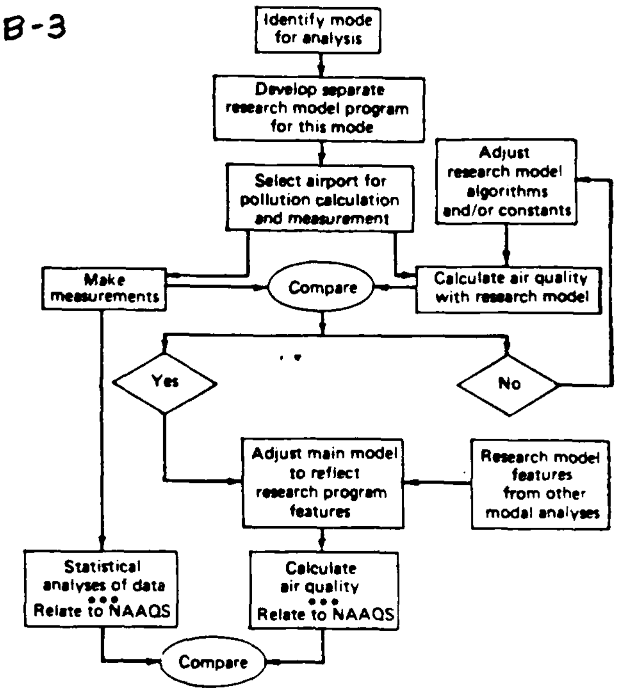


Figure 2. Analysis procedure

Results

Measurement and modeling results at five airports are summarized in Figure 3. Aircraft related concentrations have been determined through: statistical analysis of measurements, submodeling of aircraft operations at airports, and AVAP modeling of aircraft operations at airports. While there are uncertainties in each of these analysis methods, the use of three independent methods permits one to make a comparison of the consistency of the three results.

The right hand column of Figure 3 represents the results of the statistical analysis of pollution measurements after the background had been subtracted. The values selected are based either on data extrapolation to reflect the one-hour per year that the short-term standard may be exceeded or else on the average number of flights per hour times the average dose impact per flight to reflect the annual standard. The middle column represents hourly average concentrations that were estimated with a submodel that had been verified with measurement data. The left hand column represents the hourly average concentrations determined with the AVAP model, after it has been adjusted to reflect measurements of initial exhaust plume size and height, peak aircraft activity levels, and observed aircraft times in mode. The three airports used in the AVAP assessment were the same airports assessed in conjunction with the 1973 engine emission standard: John F. Kennedy (JFK), O'Hare International (ORD), and Los Angeles International (LAX).

CO Concentrations

In the right hand column of Figure 3 it is seen that a peak aircraft that were operating at Lakeland Airport, FL. Submodel calculations at LAX (middle column) and AVAP calculations at JFK, ORD, and LAX (left column) all yield peak hourly CO concentrations in the range of 4–7 ppm.

From all these data, it is seen that no estimate of peak hourly average CO concentration, at a source-receptor distance of 750 m, exceeds one-fifth of the NAAQS for CO.

NO_2 Concentrations

Measurement and model results have been compared with standards, taking into account the number of times that the standards can be exceeded. Two types of standards were considered: a long-term NAAQS (one year arithmetic mean) and a possible short-term standard (under consideration). Since one would expect this possible short-term standard to reflect the characteristics of other short-term NAAQS, this study employs concentration averaging times of 1 hr with an expected exceedance of one time per year.

NO_2 data have been analyzed to reflect both long and short-term standards. With regard to the long-term NAAQS, 0.005 ppm has been measured at 300 m from the source when aircraft depart at an hourly rate of 10.1 airplanes/hr. These data are shown in Figures 3 and 4. Even allowing for an additional factor of two variation resulting from seasonal variation of oxidant levels and/or wind direction, such levels, while small relative to the long term NAAQS, would be even smaller at the 750 m source-receptor distance used in this study.

Study data were also processed to reflect short averaging times, since a possible short-term standard[8] appeared imminent at the time that the study was started. As of the writing of this paper, the possible standard had not materialized. A different criterion was therefore sought. In 1977, a World Health Organization (WHO) task group selected 0.5 ppm (1 hr average) as their estimate of the lowest observed health effect-level for short-term exposure.[9] This value is plotted in Figure 3. (The 0.5 ppm limiting level is not to be considered a standard which would have to include an adequate margin of safety.)

The decision on how much NO_2 is chargeable to aircraft is difficult to make since NO_2 is generated both in the engine during combustion and in the ambient air through the reaction of ambient pollutants, including ozone, with engine produced NO (approximately 95% of engine NO_x is released as NO). While most ambient pollutants react quite slowly with NO, O_3 reacts very quickly with NO making it the predominant precursor-NO reaction at close-in locations (less than 1000 m between source and receptor).

Recent measurements of the O_3–NO reaction in aircraft plumes at O'Hare International Airport (ORD) have supported the "ozone limiting" approach for estimating total NO_2 concentrations from aircraft at close-in locations. Using this approach, the NO_2 values listed in the AVAP column of Figure 3 were determined by adding the NO_2 produced in the engine to the NO_2 produced by the reaction of engine produced NO with ambient O_3. Since there is usually a surplus of NO at critical pollution assessment times, O_3 concentration is the major limit to the amount of NO_2 produced in the ambient air at close-in locations. Since high O_3 levels would be expected during worst case conditions, the limiting level of the O_3 NAAQS (0.12 ppm) was assumed. As a result, 0.12 ppm of O_3 would react with an equivalent concentration of engine produced NO to produce 0.12 ppm of NO_2.

This 0.12 ppm, when added to the 0.02 ppm produced in the engine results in a total NO_2 concentration of 0.14 ppm. This value is plotted in the left hand column of Figure 3.

The NO_2 value of 0.2 ppm in the right column represents the average of the NO_2 values determined from DCA measurement data. Again, as with the CO and NO_2 data reported earlier, concentrations at the measurement distance of 300 m

Table I. Characteristics of pollution monitoring programs.

Airport	Objective	Technique	Monitoring Duration	Monitoring Mode	Aircraft Activity (Departures Per Hour)	Types of Aircraft	Relevant Model	Documentation Date and Reference
CO Monitoring								
Dulles International (IAD)	Define low thrust plume dimensions and rise for inclusion in AVAP	Three-80 ft vertical towers	1 yr (5/76–5/77)	Taxi	Moderate-(11/hr)	Commercial (all types)	Research submodel for AVAP improvement	12/77 Ref. 3
Lakeland, Florida	Model Verification for very high activity taxi queue of general aviation aircraft	Precise recording of aircraft activity and pollution dispersion	1 week (Jan. 1978)	Taxi	Very high-(273/hr)	General aviation	Simplex	1/78-Ref. 5
Washington-National (DCA)	Monitoring of emissions from queuing aircraft at congested airport	High rate data logging of concentrations and meteorological parameters (one data point every 3 sec.)	1–2 months (Jan.–Feb. 1979)	Queuing (Prior to take-off)	High-(20/hr)	Commercial (short range only-727, 737, DC-9)		7/80-Ref. 2 1980-Ref. 6
[illegible]	[illegible]	[illegible]	1 week	Queuing	High (20/hr)	Commercial	Simplex	6/80-Ref. 7

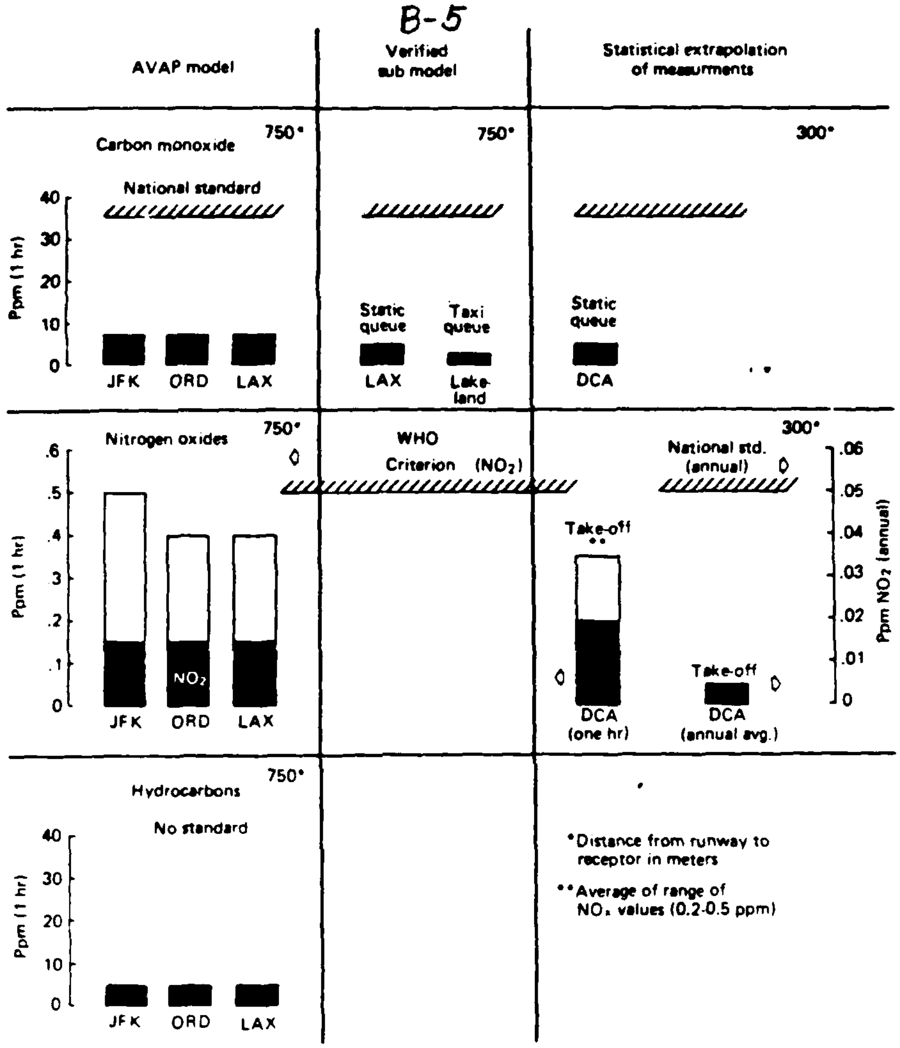


Figure 3. Summary of modeling and measurement data

shown in Figure 4 would be even lower at the characteristic 750 m source-receptor distance used in this study.

HC Concentrations

The results of AVAP modeling at JFK, ORD, and LAX, tabulated in Figure 3, indicate that peak hourly concentrations from aircraft are approximately 5 ppm. Since there is no HC NAAQS, this concentration cannot be related to any particular standard.

Conclusions

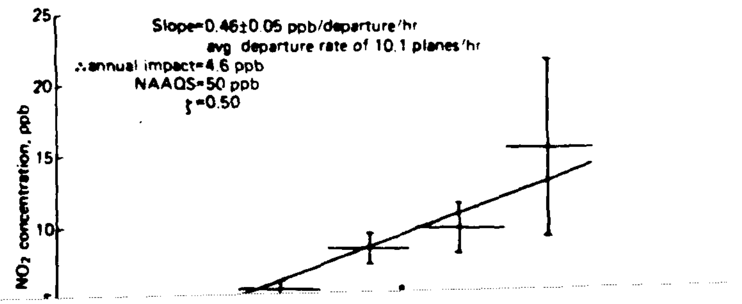
Data from Figure 3 on the impact of aircraft emissions on air quality can be summarized as follows:

For CO, 1 hr average concentrations do not exceed 7 ppm when concentrations are determined under conditions compatible with the NAAQS. This value is small relative to the 35 ppm limiting level of the NAAQS.

For NO_2, annual average concentrations are only 10–20% of the NAAQS. Short-term NO...

The impact of aircraft HC (and NO_x) emissions on oxidant levels are not addressed in this study because of the state-of-the-art limitations in the photochemical modeling and monitoring of aircraft emissions.

CO and NO_2 pollution from aircraft appears to be small relative to pollution limits in the NAAQS. This is caused by enhanced initial dispersion due to the heat and turbulence



associated with jet exhaust plumes and the strong localization of aircraft emissions at areas near the ends of runways and, consequently, quite remote from locations of public exposure. These factors, not present in the case of automobile pollution, act to mitigate the significance of pollution from aircraft.

Acknowledgments

The results of this study were achieved through the cooperation of persons from Argonne National Laboratory (ANL), Environmental Research and Technology (ERT), the EPA, the FAA, and the Air Force.

The FAA contracted study reported in this paper was performed by Dr. S. Bremer, and D. Lamich of ANL and Dr. D. Smith, D. Heinold, and B. Taylor of ERT.

The EPA involvement in this study included the activities of R. Drago, who was responsible for the extensive instrumentation at DCA; J. Dicke and S. Eigsti, who were responsible for data analysis and Dr. B. Jordan and G. Kittredge who coordinated the program from a regulatory and technical standpoint.

Major Dennis Naugle of the Air Force provided technical and funding support to the tower experiments at Dulles International Airport and acted as a technical advisor.

The reviews, results, and conclusions expressed in this paper are those of the authors and do not of necessity reflect the policy of the FAA or ANL.

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APPENDIX C

SIMPLEX "A" - A SIMPLIFIED ATMOSPHERIC DISPERSION MODEL FOR AIRPORT USE - (USERS GUIDE)

C-2

FAA-EE-81-8

U.S. Department of Transportation
Federal Aviation Administration

Simplex "A" -A Simplified Atmospheric Dispersion Model for Airport Use-(Users Guide)

Office of Environment
and Energy
Washington, D.C. 20591

Technical Report Documentation Page

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9. Performing Organization Name and Address U.S. DEPARTMENT OF TRANSPORTATION FEDERAL AVIATION ADMINISTRATION OFFICE OF ENVIRONMENT AND ENERGY, AIR QUALITY DIV. WASHINGTON, D.C. 20591		10. Work Unit No. (TRAIS) 11. Contract or Grant No. N/A
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16. Abstract

The method, limitations and uses of the SIMPLEX "A" atmospheric dispersion model are described. The model determines pollutant concentrations from taking-off aircraft and has the flexibility to easily accept parameter changes. It can treat either single or multiple aircraft departures and permits air quality calculations to be made by persons without an extensive computer background. The program is listed and the results of two sample problems are given to illustrate the use of the model.

This is a research model with many of its dispersion and turbulence parameters still under investigation. As such it has not been adopted by the FAA for formalized pollution assessments.

17. Key Words	18. Distribution Statement
AIR QUALITY AIRCRAFT EMISSIONS AIRPORT POLLUTION	This document is available to the public through the National Technical Information Service,

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INTRODUCTION

Atmospheric dispersion models are mathematical expressions that combine source emissions with meteorological parameters to produce air quality estimates at specified receptor locations. At airports where many sources and receptors are involved, refined models such as the Airport Vicinity Air Pollution model (AVAP)(1) are used to determine air quality. However, where few sources and receptors are involved, screening models are very attractive for identiying the need for further analysis with the more refined models. This report describes one of these screening models, SIMPLEX "A".

This report describes the mathematical basis for the model, lists the program, and explains the steps taken to compute pollution dosage. Special program features are described and two sample problems are solved.

The experienced user, who is primarily concerned with running a specific problem, may bypass the descriptive sections of this report and proceed directly to the "Sample Problem-Program Operation" section on page 5.

MODEL DESCRIPTION

SIMPLEX "A", which has been programmed for the Hewlett Packard 67 and 97 desk calculators, addresses emissions during takeoff. Additional SIMPLEX models are being developed to determine the air quality impact from taxiing and queueing aircraft as well as from ground vehicles at the airport. The model is particularly useful at small airports and at those airports having only a few dominant sources.

SIMPLEX "A" uses the same Gaussian formulation employed in many of the refined models listed in the Environmental Protection Agency's (EPA) guidelines on air quality models. It accomplishes its function by simplifying many of the detailed features of the more refined models. The model is an integrated puff model for an accelerating point source. Downwind receptors are assumed to be at ground level (z=0) and receive pollution doses from each emission puff. Figure 1 describes the source-receptor geometry where the dose from each emission puff is summed at a receptor to give a total dose due to a complete takeoff event. Concentrations are measured in parts per million (ppm) of Nitrogen Dioxide (NO_2) where the complete conversion of Nitrogen Oxides (NO_x) to NO_2 is assumed. In cases where Carbon Monoxide (CO) concentrations are required, NO_2 calculations can be factored appropriately. The total dose at point x,y,0 is given by the equation:

1 $$\Psi' = \frac{Q}{\pi \sigma_{z_T} \sigma_{Y_T} U} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_{z_T}}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{Y}{\sigma_{Y_T}}\right)^2\right] \quad (2)$$

SYMBOL	DEFINITION	UNITS
Ψ' =	receptor exposure of dose	ppm-sec. (NO_2)
X =	downwind distance in the direction of the mean wind	meters (m)
Y =	crosswind distance	m

z =	height above ground level	m
σ_{z_T} =	standard deviation of plume concentration in the vertical direction	m
σ_{y_T} =	standard deviation of plume concentration in the crosswind direction	m
U =	wind speed	m/sec
Q_T =	total emissions during an emission release	grams
H =	effective height of emissions	m

The program is printed out in Figure 2. The registers, labels, inputs and outputs are listed in Figures 3 and 4.

SPECIAL PROGRAM FEATURES

Standard Deviations of Plume Concentration (sigma (σ))

A subprogram was employed to determine the standard deviation of plume concentration in the horizontal (crosswind) and vertical directions. This subprogram was based upon the assumption that pollution disperses according to the power law expression.

2 $$\sigma = Kx^b \quad \text{or, in straight line form}$$

3 $$\text{Log } \sigma = b \text{ Log } x + \text{Log } K$$

The exponent "b" governs the rate of pollutant dispersion and the coefficient "K" depends upon atmospheric stability.

Analysis of the Pasquill/Gifford curves* (3) used in most dispersion models shows that for stability classes "B" through "E", single straight lines are approximated when σy and σz values are plotted logarithmically against downwind distance up to a source-receptor distance of 1000 meters. It is also seen that these straight lines have the same slope.

With the realization that σ as a function of four stability classes can be represented as single straight lines with the same slope (0.9), equation 2 can be rewritten as:

4 $$\sigma y = K_1 x^{0.9}$$

5 $$\sigma z = K_2 x^{0.9} \quad \text{when x does not exceed 1000 meters}$$

The values of K_1 and K_2 which are listed in the program printout (Figure 2) were obtained by solving equations 4 and 5 for K_1 and K_2 after substituting values for x, σy and σz.

The program not only allows for calculation of the σy and σz values in equations 4 and 5 but also has provisions to input values for initial sigmas (σo_z and σo_y) in order to account for the enhanced dispersion caused by the hot, high velocity jet exhaust. (This enhanced dispersion

Because of technical difficulties, it has not been possible to determine σo values from measurements taken at airports during high thrust airplane takeoff. However, plume measurements have been made during low thrust operations at Dulles (4) and Los Angeles International (7) airports. Average values from measurements taken at these two airports (8 meters for σo_z and 16 meters for σo_y) are incorporated in the model.

Plume Height

Because of the lack of experimental data to support plume rise theories for taking-off aircraft, special plume rise algorithms have not been incorporated into the model. While research is planned in this area, until this research is completed, it was assumed that the plume height was at least as high as the airplane engines. An average value for this parameter is four meters for airplanes operatng at a typical large airport.

Stability Class

Pasquill/Gifford stability classes "B", "C", "D", and "E" are expected to prevail at the airport during the times of air quality assessment. Turner (3) gives a detailed description of the characteristics of each stability class. A particular stability class is identified by a range of wind speed, solar radiation intensity, and cloud cover. Values for these parameters can be obtained from local National Weather Service or observer personnel.

Winds

The coordinate system is oriented to the runway on which the aircraft are assumed to be operating. Since aircraft usually take off into the wind, wind angles are measured only from 0 to 90 degrees on either side of the runway. For example, a zero degree wind would blow directly down the runway; a 90 degree wind would blow perpendicular to the runway.

Acceleration

Aircraft performance manuals can be used to determine acceleration during takeoff. However, the program has been structured to accept an average takeoff acceleration and performance information should be adjusted to average acceleration values.

Emission Tail

During the operation of a jet engine, the high velocity of its exhaust gases creates an emission tail which can extend for a considerable distance behind the aircraft (Figure 5). This tail is simulated by assuming a value for its length and by assuming a finite number of points along the tail at which emissions are considered to be released. Observations of the tail length of a number of aircraft enabled the

The program assumes a 225 meter emission tail with three emission release points located 75 meters apart in the tail (see Figure 5). The model is programmed to index the emission starting point 75 meters further down the tail after each iteration sequence is completed. The first and last points in the tail are 37.5 meters from the ends of the tail. (The tail starts at the exit plane of the engine.)

Vertical Dispersion Lid

Calculations under a variety of assessment conditions showed that a lid on vertical dispersion, i.e. an inversion "cap", had an insignificant effect on concentration at the short downwind distances (less than 1000 meters) employed in assessing aircraft pollutant impact. An algorithm to account for this phenominon is, therefore, not included in the program.

Iteration Interval

From past program use, a one-second iteration time is recommended. Using this iteration time interval, the dose calculation can be completed in less than 15 minutes at a source receptor distance of 300 meters.

Dosage Output

Total dosage is printed out at the end of each iteration sequence. The program is stopped when the dosage reaches a maximum value. Output units are parts per million-seconds (ppm-seconds). To determine the average concentration over a one-hour time period (for compatability with a particular short term standard) the dosage must be divided by 3600 seconds.

SAMPLE PROBLEM

The step by step procedure for solving the sample problems is described in this section. While this procedure is structured for a single aircraft, the same procedure can be used for any number of aircraft by treating them as one large aircraft.

Preparation of Data For Program Execution

From Figure 1 it is seen that the Case 1 receptor is located 337.5 meters downwind from the aircraft (as measured along the runway) and 200 meters abeam of the runway centerline. The Case 2 receptor is located 262.5 meters upwind of the aircraft and 100 meters abeam to it.

The objective of this problem is to determine the air quality impact of 747 NO_x emissions (reported as NO_2) during takeoff. During this takeoff, it was assumed that a 5-meter per second wind was blowing at 30 degrees to the runway centerline and that Pasquill/Gifford stability class "E" prevailed. The 747 was assumed to have a constant takeoff acceleration

The following procedure was used in solving the problems: Source emissions were obtained from AP-42 supplement 10 (8), where 747 NO_x emissions are listed at 215.3 kilograms per hour per engine or 60 grams per second per engine. Since the 747 has four engines, the total emission rate was 240 grams per second. To accommodate the three emission release points in the "tail" (see Figure 5) this rate was divided by 3 to reduce its value to 80 grams per second per "tail" release point. Selecting an iteration time of one second and multiplying it by the emission rate results in the release of 80 grams of NO_x per puff.

σo_z and σo_y values of 8 and 16 meters respectively were selected from the Standard Deviation of Plume Concentration section of this report and a plume height of 4 meters was selected from the plume height section. The beginning time was set at zero by inputting the iteration time (one second) and assigning a negative sign to it. The Case 1 receptor is downwind of the aircraft giving it a positive sign (see Figure 1). The Case 2 receptor is upwind of the aircraft giving it a negative sign. The airplane to receptor distance is converted to a "tail" to receptor distance (at the first "tail" emission point, see Figure 5) by subtracting 37.5 meters from the former to uniformly space the three tail release points over the 225 meter tail length. The resulting distance between the receptors and the first point in the emission tail is +300 meters for Case 1 and -300 meters for Case 2.

Program Operation

Load the Program

Before loading the program the "on-off" switch should be in the "on" position and the "run-program" switch should be in the "run" position (for the HP-97 the "trace-manual-norm" switch should be in the "manual" position). The program can then be loaded into the calculator by first pushing the number 1 end of the magnetic tape strip* into the slot in the upper left hand portion of the HP-97 calculator. (On the HP-67 calculator the slot is located on the right hand side.) When the strip comes out the other side, turn it around to the number 2 end and push it through the slot a second time. The program is now loaded into the calculator and the tape strip which has come out the back of the calculator can be stored in the horizontal slot just under the calculator switches.

Input Data

Inputs for the Case 1 and Case 2 problems are listed in Figures 6 and 7 and a printout of the results is listed in Figures 8 and 9. The Case 1 problem is solved by first entering the values for the six input parameters listed in Figure 6 into the Primary Register by depressing the following keys: 80 STO 0 8 STO 2 4 STO B 30 STO D 1 STO E 5 STO I. Any input errors can be erased by depressing the CLx key or by turning off the calculator, restarting it and reloading the program.

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* This tape strip can be obtained by contacting the Federal Aviation

After the primary register has been loaded the secondary register is loaded by depressing the following keys: "f" "P-S"* 300 STO 0 200 STO 4 16 STO 6 1 CHS** STO 7 1.3 STO 8 "f" "P-S*.

Program Execution

The program is started by depressing the "E" key for the assumed "E" stability (The "B", "C", and "D" keys will start the program for "B", "C", and "D" stability classes respectively). The resulting three numbers printed out on the HP-97 or displayed on the HP-67 after each iteration is completed are; (1) time (in seconds) from the program start; (2) distance (in meters) that the point in the emission tail has moved down the runway; and (3) total dose (in ppm-seconds) that the receptor has received.

It is noted that after 20 iterations, the dose value will reach a maximum of 82.16 ppm-sec. This value represents the dose received at the receptor from the first emission release point in the "tail". When the dose converges on this maximum value (when all concentration digits remained unchanged out to the second decimal point) the R/S key is depressed to stop the program. The "A" key is then depressed to clear registers and index the starting point to the second tail position. The "E" key is then depressed a second time to start the next computation. Again when the dose value levels off at 55.59 ppm-sec., the "R/S" key is depressed to stop the program. Depressing the "A" key and then, after the display stops flashing, the "E" key, permits the last computation to be completed which results in a dosage of 40.85 ppm-sec. for the last tail point. After reaching this last convergence value, the program is terminated by depressing the R/S key. The person making the calculation can then sum the three dose values and divide them by 3600 to produce a one-hour concentration of 0.05 ppm.

CONCLUSIONS

The method, limitations and use of the SIMPLEX"A" model have been described. The program can determine concentrations from departing aircraft and has the flexibility to easily accept parameter changes. It can treat either single or multiple events and permits air quality calculations to be made by persons without an extensive computer background. The model can assist in determining the impact of aircraft emissions on air quality in conjunction with requirements for controlling engine emissions and can be used as a screening tool in evaluating the air quality impact of proposed Federal actions at airports.

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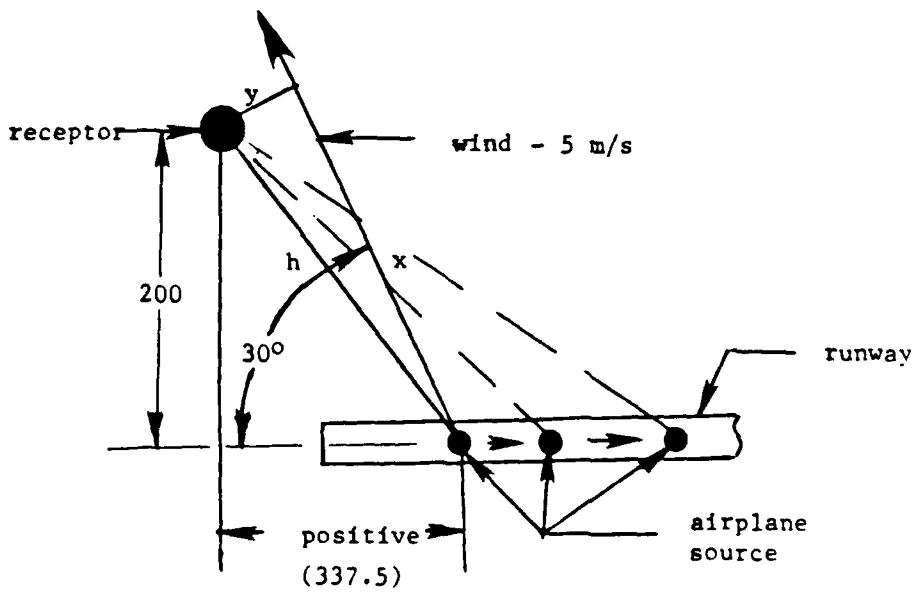
* The P-S command is input by depressing the "CLx" key on the HP-97 and the "CHI" key on the HP-67 calculator.

** Negative numbers are entered into the Hewlett Packard calculators by depressing the appropriate number key followed by the "CHS" key.

Figure 1

SOURCE-RECEPTOR GEOMETRY DURING TAKEOFF



Case 1

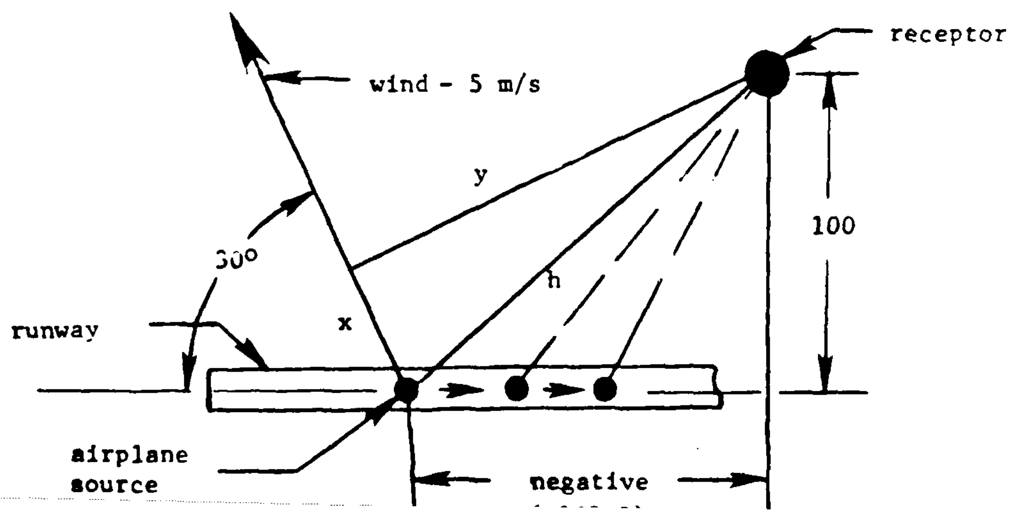


Figure 2

PROGRAM PRINTOUT

```
001  *LBLA
002   RCL3
003   X=0?
004    P⇄S
005   RCL0
006   X≠0?
007   GTO5
008   GTO6
009  *LBL4
010      0
011   STO2
012   RCLE
013    CHS
014   STO7
015    P⇄S
016    R/S
```

Clears registers and provides input data to start new iteration sequence.

```
017  *LBLB
018      .
019      9
020   STO4
021   STO6
022      .
023      1
024      7
025   STO5
026      .
027      3
028      0
029   STO7
030   GTO8
031  *LBLC
032      .
033      9
034   STO4
035   STO6
036      .
037      1
038      2
039   STO5
040      .
041      2
042      0
043   STO7
044   GTO8
045  *LBLD
046      .
050      .
051      0
052      7
053   STO5
054      .
055      1
056      3
057   STO7
058   GTO8
059  *LBLE
060      .
061      9
062   STO4
063   STO6
064      .
065      6
066      5
067      4
068   STO5
069      .
070      1
071   STO7
072   GTO8
```

Stores meteorological exponents and coefficients for stability classes "B" thru "E".

```
073  *LBL8
074    P⇄S
075   RCL0
076   RCL7
077   RCLE
078      +
079   STO7
```

Adds iteration time to total time and stores.

```
080    SPC
081   PRTX
082     X²
083   RCL6
084      ×
085      2
086      ÷
087      +
088   STO5
089   PRTX
```

Moves airplane to new location in accordance with time and acceleration values.

```
090     X²
091   RCL4
092     X²
093      +
094     √X
095   STO9
```

Performs trigonometric calculation to obtain hypotenuse "h" (see Figure 1)

```
100      ÷
101   TAN⁻¹
102   X<0?
103   GSB9
104   RCLD
105      -
106   X<0?
107    CHS
108    COS
109   X<0?
110   GTO7
111   RCL9
112      ×
113    P⇄S
114   STO1
```

Performs trigonometric calculation to determine "x" distance.

```
115     X²
116    CHS
117    P⇄S
118   RCL9
119     X²
120      +
121     √X
122   STOC
123    P⇄S
```

Performs trigonometric calculation to determine "y" distance.

```
124   RCL1
125   RCL3
126      +
127   STOE
128   RCL8
129   RCL4
130    Y^X
131   RCL5
132      ×
133     X²
134   STO9
135   RCL2
136     X²
137      +
138     √X
139   STOD
```

Performs calculation to determine final sigma "z" (initial plus distance-related sigma's).

```
140   RCL8
141   RCL6
142    Y^X
143   RCL7
144      ×
145     X²
146   STOA
147    P⇄S
148   RCL6
149     X²
150    P⇄S
151      +
152     √X
```

Performs calculation to determine final sigma "y".

```
160    CHS
161      ×
162    e^x
163    P⇄S
164   STO1
```

```
165   RCLC
166   RCLA
167      ÷
168     X²
169      .
170      5
171    CHS
172      ×
173    e^x
174   STO3
```

Determines value of crosswind function.

```
175    P⇄S
176   RCL6
177     Pi
178      ÷
179   RCLA
180      ÷
181   RCL9
182      ÷
183   RCLI
184      ÷
185      .
186      0
187      0
188      1
189      9
190      ÷
```

Performs dose calculation.

```
191    P⇄S
192   RCL1
193      ×
194   RCL3
195      ×
196   RCL2
197      +
198   STO2
```

Determines final dose corrected for plume height and crosswind distances and adds to previous dose sum.

```
199   PRTX
```

Prints total dose.

```
200    P⇄S
201   GTOE
202  *LBL9
203      1
204      8
205      0
206      +
207    RTN
208  *LBL7
209    P⇄S
210   GTO8
211  *LBL8
212      7
213      5
214      -
215   GTO8
```

Miscellaneous Subroutines

Figure 3

REGISTERS AND LABELS

REGISTERS

Primary

0 emission rate
1 "x" distance
2 initial sigma "z"
3 zero register
4 sigma "z" exponent
5 sigma "y" coefficient
6 sigma "y" exponent
7 sigma "z" coefficient
8 total distance (1+3)
9 sigma "z"
A sigma "y"
B plume height
C "y" distance
D wind angle
E iteration time
I wind velocity

Secondary

0 fixed source receptor distance along runway
1 plume rise factor
2 dose summation
3 sidewind "y" factor
4 fixed distance -receptor to runway
5 variable distance between source and receptor in the runway direction
6 initial sigma "y"
7 time at runway location
8 acceleration
9 hypotenuse ("h" in Figure 2)

LABELS

A program to clear registers and make required inputs for new iteration sequence
B,C,D,E, Storage of coefficients and exponents for sigma calculations - stability classes B,C,D,and E
4 subroutine for Label A
5 subroutine for Label A
6 subroutine for Label A
7 subroutine to switch registers
8 main program to move airplane along runway and to calculate dosage
9 subroutine of Label 8

Figure 4

INPUTS and OUTPUTS

INPUTS

Item	Units	Keys
Primary Register (P)		
source emissions over duration of event- emission rate x iteration time	grams	Sto 0
initial sigma "z"	meters	Stc 2
plume height	meters	Sto B
wind angle	degrees	Sto D
iteration interval	seconds	Sto E
wind velocity	meters per second	Sto I
Secondary Register		
fixed source receptor distance along runway	meters	Sto 0
fixed distance from receptor to runway	meters	Sto 4
initial sigma "y"	meters	Sto 6
beginning time	seconds	Sto 7
acceleration	meters/sec/sec	Sto 8

OUTPUTS

total elapsed time at iteration	seconds	Prnt 7
fixed source-receptor distance along runway	meters	Prnt 0
dose sum	parts per million sec.	Prnt 2

Figure 5

EMISSION TAIL GEOMETRY

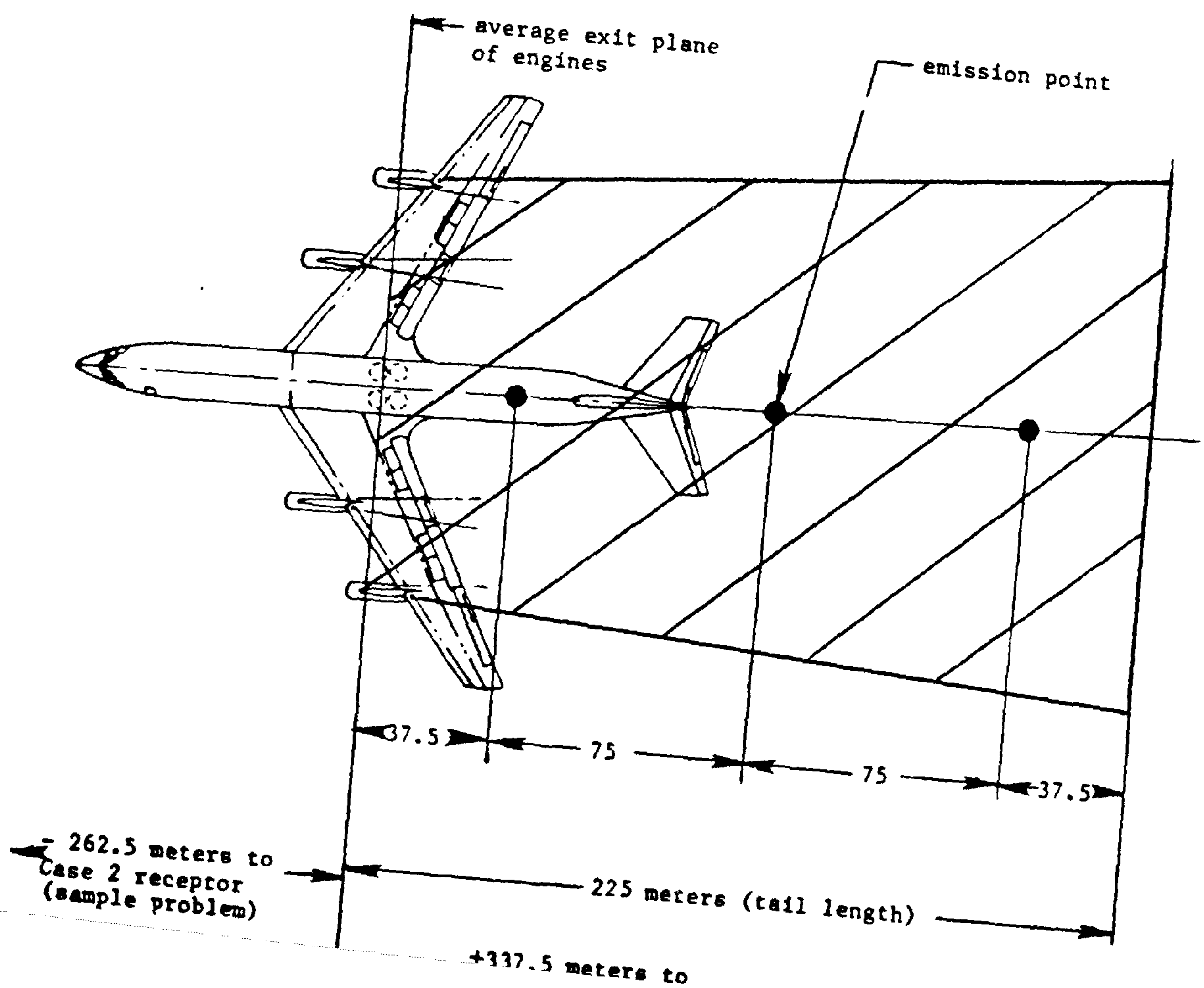


Figure 6

SAMPLE PROBLEM INPUTS - Case 1

INPUTS

Item	No./ Units		Keys*
Address Primary Register			none
source emissions **over duration of event (emiss. rate x iter. time) (80 gm/s x 1 sec.)	80	grams	Sto 0
initial sigma "z"	8	meters	Sto 2
plume height	4	meters	Sto B
wind angle	30	degrees	Sto D
iteration interval	1	second	Sto E
wind velocity	5	meters per second	Sto I
Address Secondary Register			f, P-S
fixed source receptor distance along runway	+300	meters	Sto 0
fixed distance from receptor to runway	200	meters	Sto 4
initial sigma "y"	16	meters	Sto 6
beginning time ***	-1	second	Sto 7
acceleration ****	1.3	meters/sec/sec	Sto 8
Readdress Primary Register			f, P-S

* Applicable to both HP-97 and HP-67 calculators except that the wind velocity is loaded into the HP-67 calculator by depressing the black "h" key followed by the black lettered "ST I" key.

** Possible data source - (7).

*** For a beginning time of zero, the negative value of the iterative duration must be input. This is accomplished by entering the duration value followed by the "CHS" key.

**** Possible data source - Aircraft Performance Manuals.

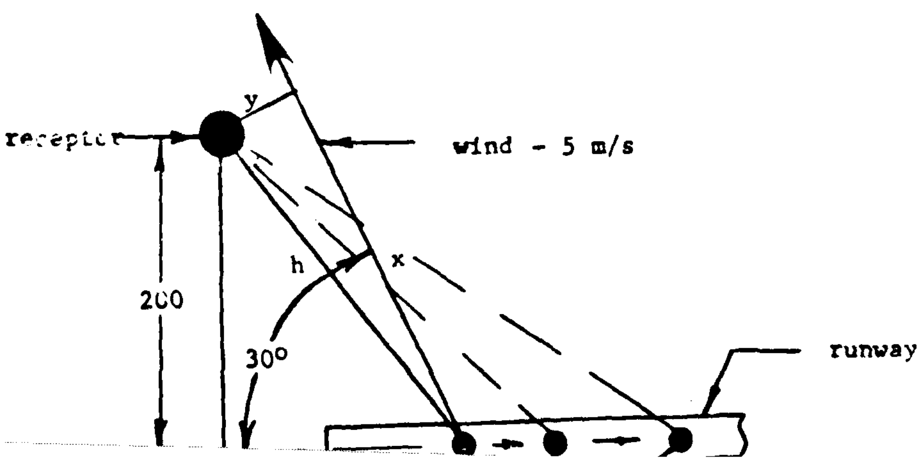


Figure 7

SAMPLE PROBLEM INPUTS - Case 2

INPUTS

Item	No./ Units	Keys*
Address Primary Register		none
source emissions **over duration of event (emiss. rate x iter. time) (80 gm/s x 1 sec.)	80 grams	Sto 0
initial sigma "z"	8 meters	Sto 2
plume height	4 meters	Sto B
wind angle	30 degrees	Sto D
iteration interval	1 seconds	Sto E
wind velocity	5 meters per second	Sto I
Address Secondary Register		f, P-S
fixed source receptor distance along runway	-300 meters	Sto 0
fixed distance from receptor to runway	100 meters	Sto 4
initial sigma "y"	16 meters	Sto 6
beginning time ***	-1 seconds	Sto 7
acceleration ****	1.3 meters/sec/sec	Sto 8
Readdress Primary Register		f, P-S

* Applicable to both HP-97 and HP-67 calculators except that the wind velocity is loaded into the HP-67 calculator by depressing the black "h" key followed by the black lettered "ST I" key.
** Possible data source - (7).
*** For a beginning time of zero, the negative value of the iterative duration must be input. This is accomplished by entering the duration value followed by the "CHS" key.
**** Possible data source - Aircraft Performance Manuals.

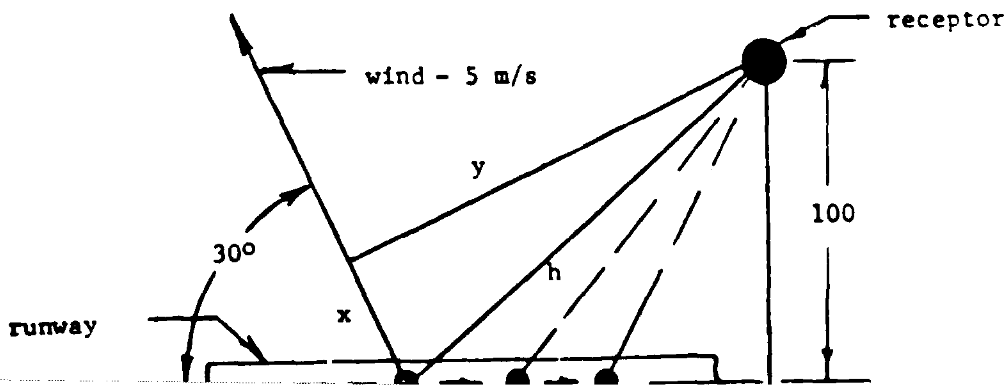


Figure 8

RESULTS - Case 1

Primary Register

80.00	0
0.00	1
0.00	2
0.00	3
0.00	4
0.00	5
0.00	6
0.00	7
0.00	8
0.00	9
0.00	A
4.00	B
0.00	C
30.00	D
1.00	E
5.00	I

Secondary Register

300.00	0
0.00	1
0.00	2
0.00	3
200.00	4
0.00	5
16.00	6
-1.00	7
1.30	8
0.00	9
0.00	A
4.00	B
0.00	C
30.00	D
1.00	E
5.00	I

Start First Iteration

time
distance
dose

0.00 ***
300.00 ***
4.95 ***

1.00 ***
300.65 ***
9.34 ***

2.00 ***
302.60 ***

3.00 ***
305.85 ***
20.49 ***

4.00 ***
310.40 ***
26.20 ***

5.00 ***
316.25 ***
32.26 ***

6.00 ***
323.40 ***
39.65 ***

7.00 ***
331.85 ***
45.27 ***

8.00 ***
341.60 ***
51.95 ***

9.00 ***
353.65 ***
58.43 ***

10.00 ***
365.00 ***
64.42 ***

11.00 ***
379.65 ***
69.62 ***

12.00 ***
393.60 ***
73.84 ***

13.00 ***
409.85 ***
77.02 ***

14.00 ***
427.40 ***
79.91 ***

16.00 ***
465.40 ***
81.40 ***

17.00 ***
487.85 ***
81.97 ***

18.00 ***
510.60 ***
82.07 ***

19.00 ***
534.65 ***
82.12 ***

20.00 ***
560.00 ***
82.16 ***

Start Second Iteration

time
distance
dose

0.00 ***
225.00 ***
0.25 ***

1.00 ***
225.65 ***
0.59 ***

2.00 ***
227.60 ***
0.93 ***

3.00 ***
230.85 ***
1.35 ***

4.00 ***
235.40 ***
1.89 ***

5.00 ***
241.25 ***
2.62 ***

6.00 ***

Figure 8 (CONT.)

```
  7.00  ***
255.85  ***
  5.16  ***

  8.00  ***
266.60  ***
  7.32  ***

  9.00  ***
277.65  ***
 10.35  ***

 10.00  ***
290.00  ***
 14.45  ***

 11.00  ***
303.65  ***
 19.59  ***

 12.00  ***
318.60  ***
 25.37  ***

 13.00  ***
334.85  ***
 31.54  ***

 14.00  ***
351.40  ***
 38.07  ***

 15.00  ***
371.25  ***
 44.59  ***

 16.00  ***
391.40  ***
 49.04  ***

 17.00  ***
412.35  ***
 52.07  ***

 18.00  ***
475.60  ***
 53.65  ***

 19.00  ***
```

```
 21.00  ***
511.65  ***
 55.48  ***

 22.00  ***
539.60  ***
 55.56  ***

 23.00  ***
569.95  ***
 55.58  ***

 24.00  ***
599.40  ***
 55.59  ***

 25.00  ***
631.25  ***
 55.59  ***

 26.00  ***
664.40  ***
 55.59  ***

 27.00  ***
699.85  ***
 55.60  ***

 28.00  ***
734.60  ***
 55.60  ***

 29.00  ***
771.65  ***
 55.60  ***

 30.00  ***
810.00  ***
 55.60  ***

 31.00  ***
849.65  ***
 55.60  ***

 32.00  ***
892.60  ***
 55.60  ***

 33.00  ***
```

Start Third Iteration

```
time                 0.00  ***
distance           150.00  ***
dose     1.67326337E-04  ***

                     1.00  ***
                   150.65  ***
           3.50699271E-04  ***

                     2.00  ***
                   152.60  ***
           5.91269467E-04  ***

                     3.00  ***
                   155.85  ***
           9.65479691E-04  ***

                     4.00  ***
                   159.40  ***
           1.64495927E-03  ***

                     5.00  ***
                   165.25  ***
           3.05515425E-03  ***

                     6.00  ***
                   173.40  ***
                     0.01  ***

                     7.00  ***
                   181.85  ***
                     0.01  ***

                     8.00  ***
                   191.60  ***
                     0.04  ***

                     9.00  ***
                   202.65  ***
                     0.09  ***

                    10.00  ***
                   215.00  ***
                     0.24  ***
```

Figure 8 (CONT.)

12.00 ***	243.60 ***	1.43 ***
13.00 ***	259.85 ***	3.12 ***
14.00 ***	277.40 ***	5.13 ***
15.00 ***	296.25 ***	10.77 ***
16.00 ***	316.40 ***	15.94 ***
17.00 ***	337.85 ***	23.53 ***
18.00 ***	360.60 ***	25.73 ***
19.00 ***	384.65 ***	34.53 ***
20.00 ***	410.00 ***	37.70 ***
21.00 ***	436.65 ***	39.45 ***
22.00 ***	464.60 ***	40.71 ***
23.00 ***	493.85 ***	40.65 ***
24.00 ***	[illegible]	[illegible]
25.00 ***	556.25 ***	40.83 ***
26.00 ***	589.40 ***	40.94 ***
27.00 ***	623.85 ***	40.95 ***

Figure 9

RESULTS - Case 2

```
 99.00   0
  0.00   1
  9.00   2
  0.00   3
  0.00   4
  0.00   5
  0.00   6
  0.00   7
  0.00   8
  0.00   9
  0.00   A
  4.00   B
  0.00   C
 30.00   D
  1.00   E
  5.00   I

-300.00  0
   0.00  1
   0.00  2
   0.00  3
 100.00  4
   0.00  5
  16.00  6
  -1.00  7
   1.30  8
   0.00  9
   0.00  A
   4.00  B
   0.00  C
  30.00  D
   1.00  E
   5.00  I

   0.00  ***
-300.00  ***

   1.00  ***
-299.75  ***

   2.00  ***
-297.40  ***

   3.00  ***
-294.15  ***
```

```
      6.00  ***
   -276.60  ***

      7.00  ***
   -269.15  ***

      8.00  ***
   -258.40  ***

      9.00  ***
   -247.35  ***

     10.00  ***
   -235.00  ***

     11.00  ***
   -221.35  ***

     12.00  ***
   -206.40  ***

     13.00  ***
   -190.15  ***

     14.00  ***
   -172.60  ***

     15.00  ***
   -153.75  ***

     16.00  ***
   -133.60  ***

     17.00  ***
   -112.15  ***

     18.00  ***
    -89.40  ***

     19.00  ***
    -65.35  ***

     20.00  ***
    -40.00  ***
4.745952363-09  ***

     21.00  ***
```

```
 23.00  ***
 43.85  ***
  0.01  ***

 24.00  ***
 74.40  ***
  5.30  ***

 25.00  ***
105.25  ***
  2.97  ***

 26.00  ***
135.40  ***
 11.55  ***

 27.00  ***
170.85  ***
 24.16  ***

 28.00  ***
205.00  ***
 31.75  ***

 29.00  ***
245.65  ***
 34.24  ***

 30.00  ***
285.00  ***
 34.74  ***

 31.00  ***
324.65  ***
 34.30  ***

 32.00  ***
365.00  ***
 34.81  ***
```

Figure 9 (CONT.) C-23

```
     0.00  ***
  -375.00  ***

     1.00  ***
  -374.35  ***

     2.00  ***
  -372.40  ***

     3.00  ***
  -369.15  ***

     4.00  ***
  -364.60  ***

     5.00  ***
  -358.75  ***

     6.00  ***
  -351.60  ***

     7.00  ***
  -343.15  ***

     8.00  ***
  -333.40  ***

     9.00  ***
  -322.35  ***

    10.00  ***
  -310.00  ***

    11.00  ***
  -296.35  ***

    12.00  ***
  -281.40  ***

    13.00  ***
  -265.15  ***

    14.00  ***
  -247.60  ***

    15.00  ***
  -228.75  ***

    16.00  ***
  -208.60  ***
```

```
          19.00  ***
        -140.35  ***

          20.00  ***
        -115.00  ***

          21.00  ***
         -88.35  ***

          22.00  ***
         -60.40  ***

          23.00  ***
         -31.15  ***
 3.186728709-08  ***

          24.00  ***
          -0.60  ***
 1.298258926-05  ***

          25.00  ***
          31.25  ***
 2.172787845-05  ***

          26.00  ***
          64.40  ***
           0.12  ***

          27.00  ***
          98.85  ***
           1.67  ***

          28.00  ***
         134.60  ***
           5.38  ***

          29.00  ***
         171.65  ***
          22.15  ***

          30.00  ***
         210.00  ***
          29.66  ***

          31.00  ***
         249.65  ***
          31.90  ***

          32.00  ***
         290.60  ***
          32.28  ***

          33.00  ***
```

```
     0.00  ***
  -450.00  ***

     1.00  ***
  -449.35  ***

     2.00  ***
  -447.40  ***

     3.00  ***
  -444.15  ***

     4.00  ***
  -439.60  ***

     5.00  ***
  -433.75  ***

     6.00  ***
  -426.60  ***

     7.00  ***
  -418.15  ***

     8.00  ***
  -408.40  ***

     9.00  ***
  -397.35  ***

    10.00  ***
  -385.00  ***

    11.00  ***
  -371.35  ***

    12.00  ***
  -356.40  ***

    13.00  ***
  -340.15  ***

    14.00  ***
  -322.60  ***

    15.00  ***
  -303.75  ***

    16.00  ***
  -283.60  ***
```

C-24
Figure 9 (CONT.)

18.00 ***
-279.40 ***

19.00 ***
-215.35 ***

20.00 ***
-193.00 ***

21.00 ***
-157.75 ***

22.00 ***
-135.40 ***

23.00 ***
-105.15 ***

24.00 ***
-75.60 ***

25.00 ***
-43.75 ***
2.001882654-03 ***

26.00 ***
-10.60 ***
2.022515555-06 ***

27.00 ***
23.85 ***
7.393883553-04 ***

28.00 ***
59.60 ***
0.07 ***

29.00 ***
95.65 ***
1.61 ***

30.00 ***
135.00 ***
5.73 ***

31.00 ***
174.65 ***
21.67 ***

32.00 ***
215.60 ***
25.45 ***

33.00 ***
257.85 ***
30.27 ***

34.00 ***
301.40 ***
30.32 ***

35.00 ***
346.25 ***
30.32 ***

36.00 ***
392.40 ***
30.72 ***

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NOTICE

The United States Government does not endorse products or manufactures. Trade or manufactures's names appear herein solely because they are considered essential to the object of this report.

APPENDIX D

MICROCOMPUTER GRAPHICS IN ATMOSPHERIC DISPERSION MODELING

D-2

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Microcomputer Graphics in Atmospheric Dispersion Modeling

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Federal Aviation Administration
Washington, DC

Detailed atmospheric dispersion models such as Airport Vicinity Air Pollution (AVAP) or Point Area-Line (PAL) can rigorously model air quality at major airports. However, at the smaller airports where fewer emission sources are present or at the larger airports where detailed analyses may not be required, a well designed screening model can save considerable time and money. Microcomputers equipped with graphics tablets are particularly attractive for this application since they are inexpensive (they can be purchased for less than $5000) and can instantaneously accept source and receptor coordinates directly from a base map with little chance of a transcribing error.

This paper describes the special features of a multiple source screening model which has been programmed for a microcomputer equipped with a graphics tablet and having 48K of random access memory. Microcomputer configuration is shown in Figure 1. The model acronym is GIMM (Graphical Input Microcomputer Model) and its status, features and results are presented.

Model Status

GIMM is an outgrowth of an earlier aircraft model, Simplex "A," which was programmed for a desk calculator. Simplex "A" was developed to fulfill the need for a screening model for aircraft sources. With the advent of microcomputers, Simplex "A" was reprogrammed to further simplify the assessment process. During this reprogramming, a method was developed to instantaneously input source and receptor coordinates into the microcomputer directly from a base map with little chance of a transcribing error. This approach, which appeared so effective for aircraft sources, was then applied to other airport sources such as roadways, power plants, parking lots, etc., in order to eliminate input errors and simplify model usage. Algorithms for each of these sources were then batched to-

Figure 1. Microcomputer configuration for dispersion modeling.

velop emission and dispersion models for use by field personnel.

Model Features

Point and Line Source Considerations

Concentrations from point and line sources are determined with the classical point source equation.[4]

$$\chi(x,y,0;H) = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left[-0.5\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-0.5\left(\frac{H}{\sigma_z}\right)^2\right] \quad (1)$$

The above equation, which is used once for each point source, is used a number of times iteratively for line sources. Concentrations from line sources are determined by dividing a line

D-3

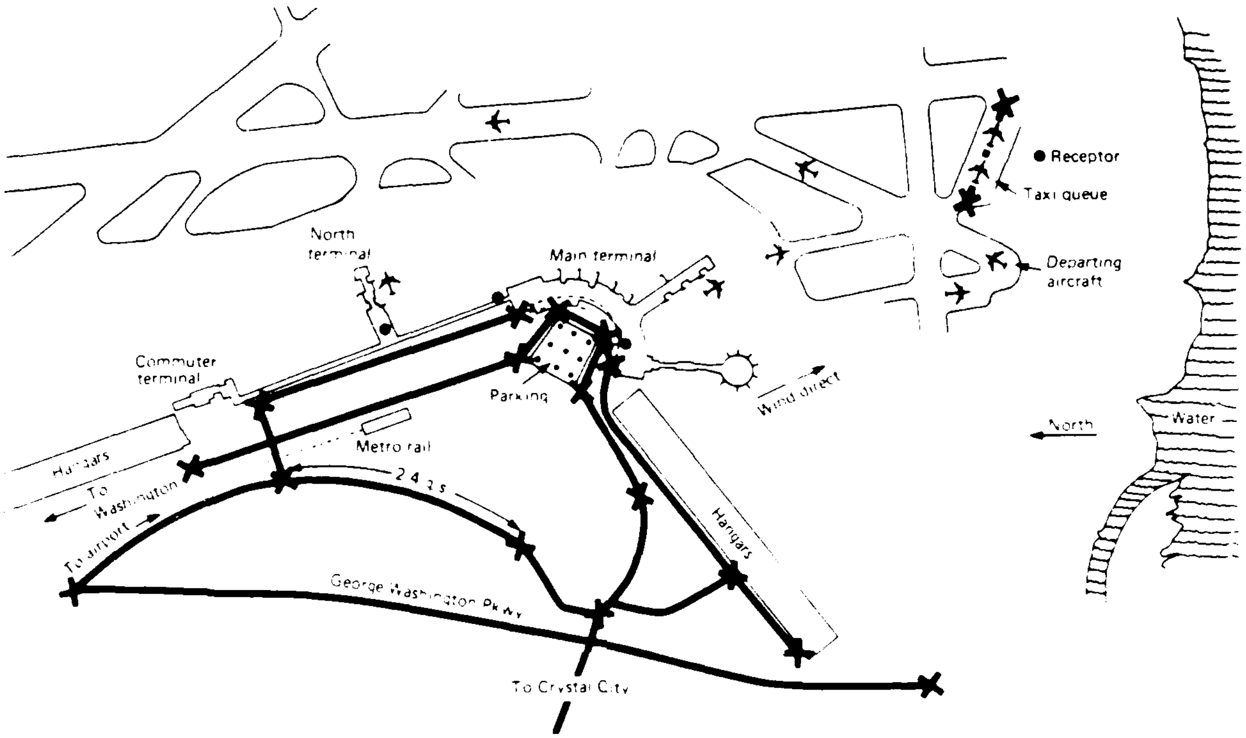

Figure 2 Source-receptor geometry at Washington National Airport

Area Source Considerations

A firm decision has not been made on whether to consider area sources as points or lines. Because points can be processed faster than lines and because they can be organized into any shaped area, a point assumption was initially used. Coordinates of each point are entered into the computer via a pen attached to a graphics tablet. This operation is quite fast; one point can be entered into the computer and concentrations calculated in less than three seconds. While nine points were used to simulate the short-term parking area at Washington National Airport (DCA) (Figure 2), the use of additional (or fewer) points is under investigation to help arrive at an optimum number of points to employ in area source simulation.

Accelerating Point Source Considerations

The algorithm for accelerating point sources is described in detail in the Simplex "A" Users Guide. This algorithm is based upon the assumption that an accelerating point source (i.e., a taking off aircraft) releases its emissions as a series of doses. Figure 3 shows the source-receptor geometry which employs the following equation.

$$\psi \; [illegible] = \frac{Q_1}{\pi \sigma_y \sigma_z u} \exp\left[-0.5\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-0.5\left(\frac{H}{\sigma_z}\right)^2\right] \qquad (2)$$

The doses from each 1-s emission puff are summed to give the total dose at a receptor due to a complete takeoff event. The program stops when the incremental dose increase becomes insignificant. Since the air quality impact of the major aircraft pollutants becomes insignificant at only short distances above the ground, climb-out and descent algorithms have been omitted from the GIMM program.

Results

In order to determine how long it would take to enter data in GIMM and run it, a standardized scenario listed in the PAL User's Guide was used. This scenario consisted of a combination of 19 point, area, line, and accelerating aircraft sources and 5 receptors. GIMM accepted these data in 15 min and calculated concentrations in 1½ h. Corresponding times for an actual airport (DCA) were 10 min and 1¼ h respectively. Aircraft sources alone were then run with the GIMM model for 3 source-receptor scenarios listed in the PAL User's Guide. Two versions of GIMM were employed: the first with lower computational accuracy but higher computer execution speed, and the second with higher computational accuracy but lower computer execution speed. The higher speed version, which increased execution speed by 25%, was accomplished through a power law fit rather than a quadratic fit to the Pasquill

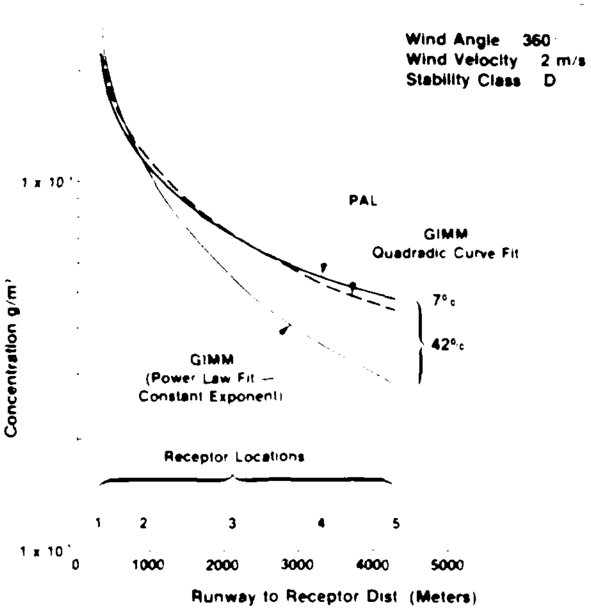

Figure 4 Concentration at different distances from the runway.

power law version at the close in distances and the quadratic version at the further out distances. Key questions being considered are: (1) How accurate does the computation have to be? (2) What execution time is acceptable? (3) What source-receptor distances are likely to be used?

Conclusions

The particular strength of a microcomputer in complex source modeling is its graphical input capability. This advantage is particularly useful when it is necessary to input a large number of sources, such as one would find at an airport, airbase or other complex source.[6]

A microcomputer model appears feasible for screening purposes because it does not require excessive computer run time and its computational results compare favorably with those of an established EPA model. The model appears to be *particularly user friendly and therefore requires little tech*nical supervision of the person doing the modeling. The model should also improve the quality of an assessment effort because of the precise manner in which source and receptor information is entered into the computer.

Nomenclature

H = effective height of emissions
Q = emission rate
Q_T = total emissions released during a finite time period
u = wind speed
X = receptor concentration
x = downwind distance in the mean wind direction
y = crosswind distance
σ_y = standard deviation of plume concentration in the crosswind direction
σ_z = standard deviation of plume concentration in the vertical direction
ψ = receptor exposure or dose

Acknowledgments:

The author appreciates the dedicated and extra efforts of Mr. Paul Hamilton and Mrs. Hazel Medville in the preparation of some of the information of this paper. Their work was funded under FAA contract DTFA01-82-Y-10510 to Wilson-Hill Associates.

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APPENDIX E

POLLUTION FROM MOTOR VEHICLES AND AIRCRAFT AT STAPLETON INTERNATIONAL AIRPORT (Abbreviated Report)

E-2

POLLUTION FROM MOTOR VEHICLES AND AIRCRAFT AT STAPLETON INTERNATIONAL AIRPORT

(ABBREVIATED REPORT)

U.S. Department of Transportation
FEDERAL AVIATION ADMINISTRATION
Office of Environment and Energy
Washington, DC 20591

E-3

Technical Report Documentation Page

1. Report No. FAA-EE-86-11-A /REV 2	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle POLLUTION FROM MOTOR VEHICLES AND AIRCRAFT AT STAPLETON INTERNATIONAL AIRPORT (ABBREVIATED REPORT)		5. Report Date December 1986/REV1-April 1987
		6. Performing Organization Code REVISION 2 - September 1987
7. Author(s) HOWARD M. SEGAL		8. Performing Organization Report No.
9. Performing Organization Name and Address FEDERAL AVIATION ADMINISTRATION OFFICE OF ENVIRONMENT AND ENERGY 800 INDEPENDENCE AVENUE, SW. WASHINGTON, D.C. 20591		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address		13. Type of Report and Period Covered AIRPORT POLLUTION ANALYSIS
		14. Sponsoring Agency Code AEE-30

15. Supplementary Notes

THE FULL REPORT, WHICH INCLUDES ALL APPENDIX PRINTOUTS, IS DESIGNATED FAA-EE-86-11/REV1

16. Abstract

The air quality impact of the proposed runway expansion program at Stapleton International Airport is determined in this report. The method of analysis is to model the dispersion of pollutants from motor vehicles and aircraft under both 1-hour and 8-hour worst case conditions.

Results show that aircraft pollution concentrations are reduced and in some cases completely disappear when the new runways are added. This is caused primarily by a reduction in takeoff delays, which are a major objective of the runway expansion program at the airport.

17. Key Words	18. Distribution Statement
AIR, POLLUTION, DISPERSION MODEL, EMISSIONS MODEL, MICROCOMPUTERS	THIS DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

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TABLE OF CONTENTS

SUMMARY

Most pollution from aircraft at Stapleton International Airport (DEN) is the result of pre-takeoff delays. These delays result in aircraft queues which increase the time that aircraft engines must operate on the ground. In just about every case these queues, and the pollution they create, are reduced or completely eliminated when new runways are added.

This conclusion was based upon current estimates of peak hour motor vehicle and aircraft activity at the airport and the application of these peak hour values to all hours modeled. This approach provided conservative air quality estimates for the two 8-hour meteorolgical data sets provided by the Colorado Department of Health (CDH) since both data sets extended into the late evening hours where there was little aircraft or motor vehicle activity.

A major result expected from the runway expansion at Stapleton International Airport is reduced delays and therefore reduced pollution from aircraft.

BACKGROUND

At the request of Colorado Department of Health (CDH), the Federal Aviation Administration (FAA) conducted an analysis of motor vehicle pollution at DEN. This study was performed in conjunction with the runway expansion investigations at the airport. On July 1, the documentation of this study was transmitted to the CDH as report FAA-EE-86-7 (Reference 1).

After reviewing this report, the CDH requested the following information:

1. An assessment of pollution from both aircraft and motor vehicles using two sets of 8-hour meteorological data provided by the CDH.

2. An assessment of the pollution from motor vehicles and aircraft using 1-hour 'worst case' meteorology. This assessment would consist of the addition of aircraft to the motor vehicle analysis of Reference 1.

3. The expansion of the motor vehicle analysis of Reference 1 to include a wider variety of wind directions. The CDH recommended that wind directions of 180, 200, 225 and 330 degrees be modeled since only westerly wind directions (240 and 270 degrees) were modeled in the original study.

4. Nitrogen oxides (NO_x) estimates.

5. A determination of the air quality impact of motor vehicles at the I-70/Quebec Street interchange. (Vehicular flow rates to be

DISCUSSION

The air quality impact of the runway expansion program at DEN was determined by calculating carbon monoxide (CO) concentrations at seven receptors placed in the terminal area. The geometrical location of these receptors as related to the runways and roadways at the airport is shown in Figures 1 through 5. The tool used in assessing pollution at the airport was the Graphical Input Microcomputer Model (GIMM) (Reference 2).

Two "worst case" scenarios were prepared in order to calculate concentrations from aircraft and motor vehicles operating at the existing and expanded runway systems. Results from the first scenario analysis, which included weather observations for two specific 8-hour time periods, are plotted in Figures 6 and 7. In all instances aircraft concentrations were reduced when the new runways were added.

Results from the second scenario analysis, which employed estimated "worst case" 1-hour meteorology, is plotted in Figures 8 through 21. The highest combined aircraft-motor vehicle concentrations are shown in Figure 17. These concentrations are significantly reduced with the introduction of the expanded runway system. Appendix B lists the computer reports from which Figures 6 through 21 were prepared.

MODEL

GIMM is a complex source emissions/dispersion model with an emissions front end which allows fast and accurate data entry and "what if" analysis. The model, described in detail in Reference 2, is conceptually displayed in Figure 22.

GIMM is compared to two Environmental Protection Agency (EPA) models: Point-Area-Line (PAL) and HIWAY 2 in Figure 23 and Reference 2. The comparison shows GIMM results to be very close to those of the EPA models.

Before running GIMM it was necessary to: (1) establish source and receptor locations, (2) estimate vehicular activity, and (3) select source emission rates.

Source and receptor locations are shown in Figures 1 through 5, and the rationale for developing data on aircraft and motor vehicle activity and emission rates is described below.

DATA DEVELOPMENT - AIRCRAFT

The EPA has identified four operational modes for aircraft pollution assessment purposes: takeoff, climbout, approach and taxi-idle. For the

Only the queue and takeoff modes are included in the model analysis because climbout and approach contribute very little to the pollution burden at an airport (Reference 3). The queue times selected for this study were 15 minutes for the existing runways and 3 minutes for the proposed runway configuration. These times are consistent with capacity/demand estimates in Reference 6. Appendix C describes the adaptation of Reference 6 data to this study.

When making a screening analysis, conservative estimates should be used. Peak vehicular activity was therefore used throughout this study. The peak hour activity of aircraft was determined after reviewing documentation on actual aircraft departures and estimates of these departures that were listed in computer printouts from the Official Airline Guide (OAG). Aircraft activity at 1700 hours on August 19, 1986, was selected for this study. Eighty-one commercial, general aviation, and air taxi aircraft were estimated to depart from DEN during that hour.

Emission rates were extracted from Reference 4.

DATA DEVELOPMENT - MOTOR VEHICLES

Roadway activity was calculated from hourly traffic counts obtained from Centennial Engineering Company. Two traffic count data sets were provided by Centennial Engineering--one covering motor vehicle activity on city streets and the other covering activity along terminal roadways. Parking lot activity was also observed on August 9, 1986. Traffic counts at the Quebec/Interstate 70 (I-70) interchange were also provided verbally by Centennial Engineering. From these data, a roadway throughput analysis was prepared and vehicular flow on each roadway segment was determined. The results are listed in Figure 5.

Traffic counts on December 20, 1985, and August 9, 1986--two peak activity times for motor vehicles--were used for this roadway analysis. The traffic at the I-70/Quebec interchange was not included in the modeling analysis since we had not received these data from Colorado State personnel at the time the model was run. This information can be easily added to the study when received. Because of the great distance between this interchange and the terminal, concentrations should change little when this additional data become available.

Peak hour activity was assumed for all hours modeled regardless of whether the hour modeled was at a peak value or not. This approach provided conservative air quality estimates for the 8-hour data sets since both 8-hour data sets extended into the late evening hours when there is significantly less than peak hour activity.

Emission rates are calculated by a Mobile 3 submodel of GIMM. The

Item 1 -- An assessment of pollution from both aircraft and motor vehicles using two sets of 8 consecutive hours of meteorological data provided by the CDH.

Most pollution from aircraft is the result of pre-takeoff delays. These delays result in aircraft queues which increase the time that aircraft engines must operate on the ground. In just about every case, these queues and the pollution they create, are reduced or completely eliminated when new runways are added. A major result of runway expansion at Stapleton International Airport will be reduced delays and therefore reduced pollution from aircraft.

The air quality impact of motor vehicles alone is documented in Reference 1 and Item 3 below.

Item 2 -- An assessment of the pollution from motor vehicles and aircraft using 1-hour "worst case" meteorology. This assessment would consist of the addition of aircraft to the motor vehicle analysis of Reference 1.

The conclusion of Item 1, which was for the 8-hour analysis, also applies to the 1-hour analysis.

Item 3 -- The expansion of the motor vehicle analysis of Reference 1 to include a wider variety of wind directions. The CDH suggested the modeling of 180, 200, 225, and 330 degree wind directions because only westerly wind directions (240 and 270 degrees) were modeled in the original study.

After modeling the dispersion of pollutants under the four additional meteorological cases noted above, the assumption in Reference 1 that the highest concentrations would occur at the three receptors closest to the terminal was confirmed. However, the wind angle at which peak concentrations occured changed. Revised peak concentrations are as follows: Receptor 1 - 30 mg/m3 at a wind angle of 330 degrees; Receptor 2 - 30 mg/m3 at a wind angle of 200 degrees; and Receptor 3 - 29 mg/m3 at a wind angle of 240 degrees. These values were obtained from the passenger vehicle listings of Appendix A plus an assumed average concentration for buses of 1 mg/m3.

Item 4 -- NOx Estimates

For all the modeling runs, NOx as well as CO concentrations were printed out. Appendix B lists these data.

Item 5 -- A Determination of the Air Quality Impact of Motor Vehicles at the I-70 Quebec Street Interchange. (Vehicular flow rates to be provided by the state.)

This portion was not completed because traffic counts which were to be provided by Colorado State personnel were not received. However, it

TAKEOFF RUNWAYS AND QUEUE LENGTHS - STAPLETON INTERNATIONAL AIRPORT
(north depatures - existing runway system - peak aircraft activity)

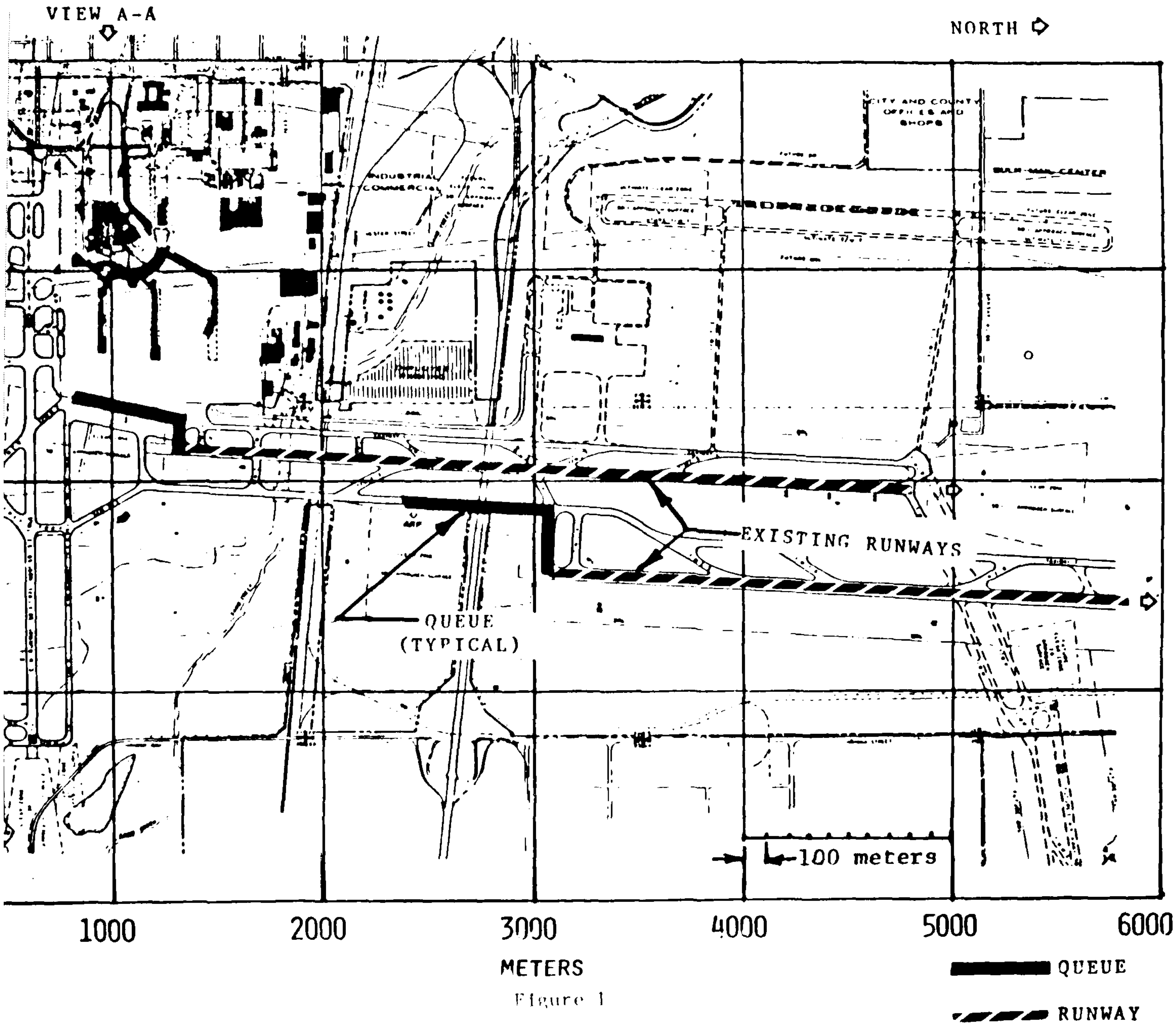

Figure 1

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'AKEOFF RUNWAYS AND QUEUE LENGTHS - STAPLETON INTERNATIONAL AIRPORT
(north departures - expanded runway system - peak aircraft activity)

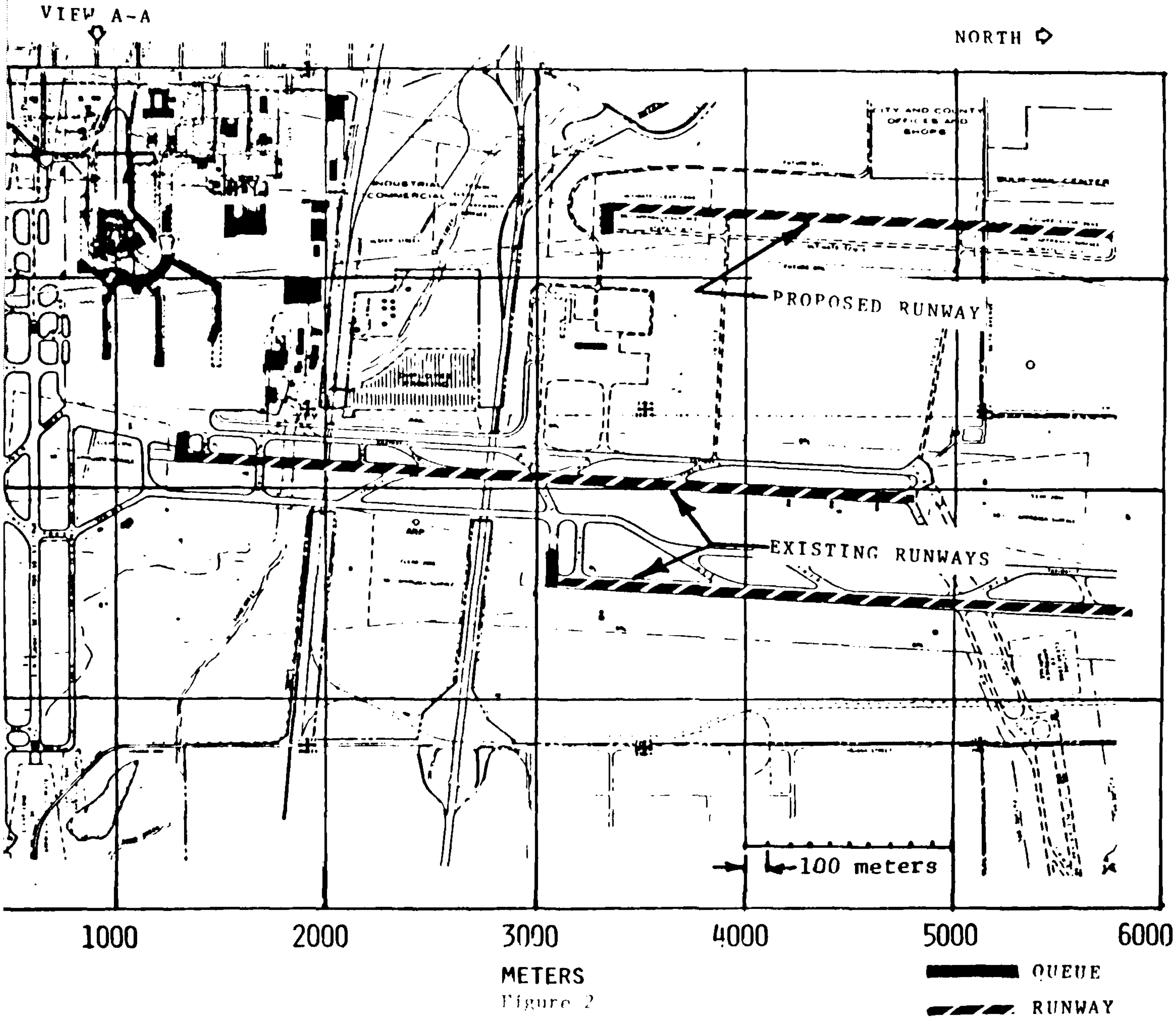


Figure 2

TAKEOFF RUNWAYS AND QUEUE LENGTHS - STAPLETON INTERNATIONAL AIRPORT
(east departures -existing runway system - peak aircraft activity)

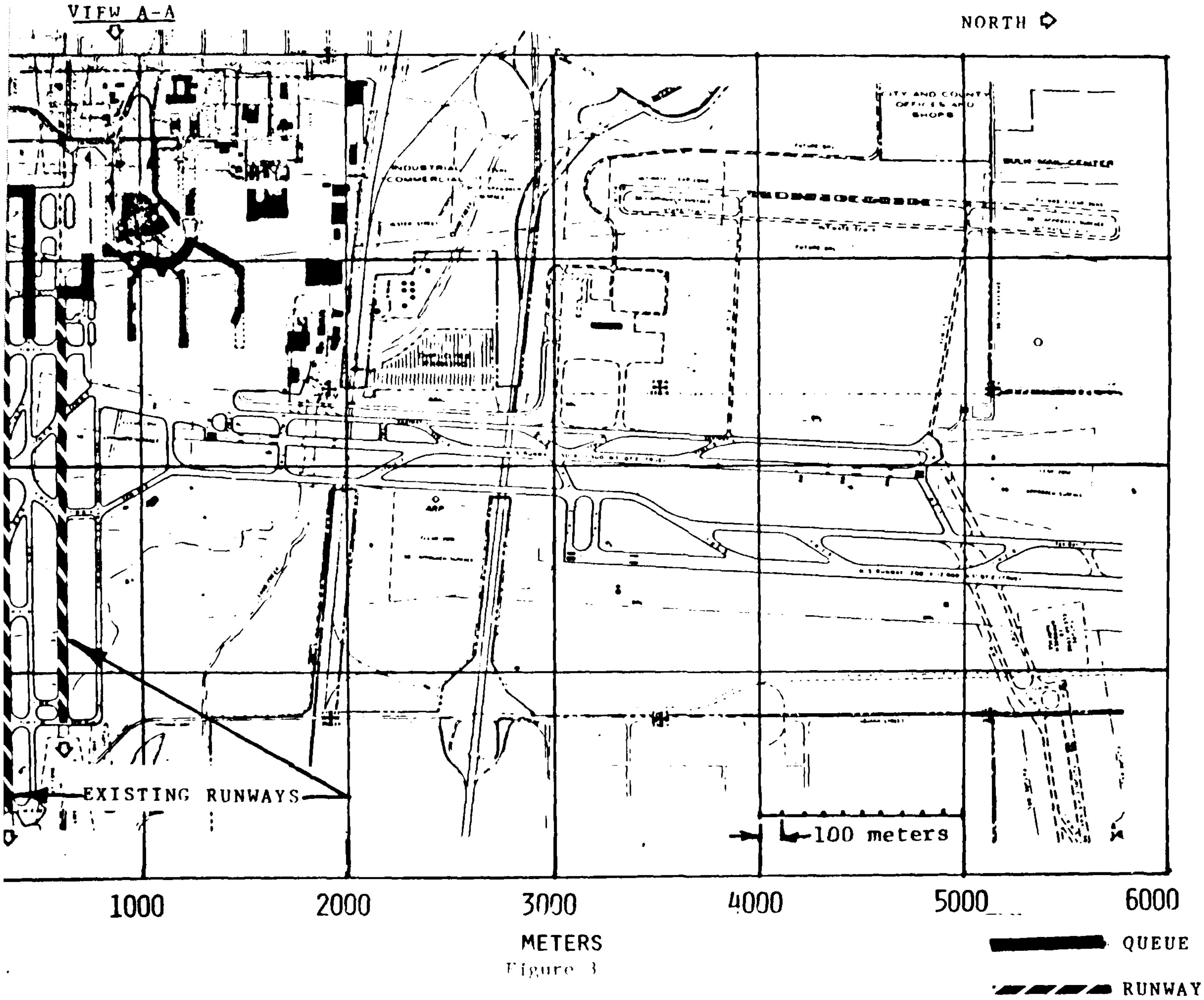


Figure 3

TAKEOFF RUNWAYS AND QUEUE LENGTHS _ STAPLETON INTERNATIONAL AIRPORT
(east departures - expanded runway system - peak aircraft activity)

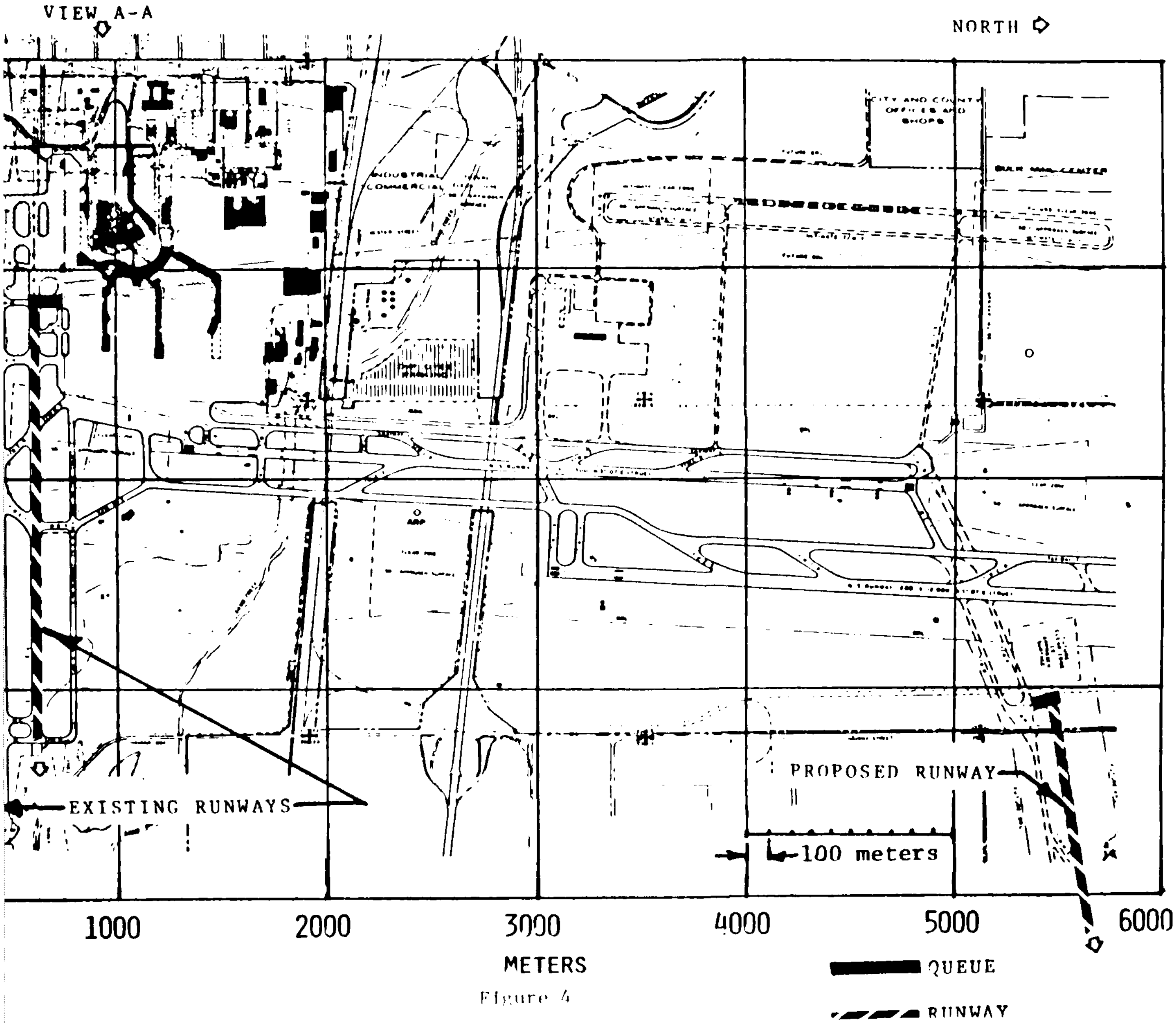


Figure 4

TERMINAL ACCESS ROADWAYS - STAPLETON INTERNATIONAL AIRPORT
(view A-A of Figures 1-4)

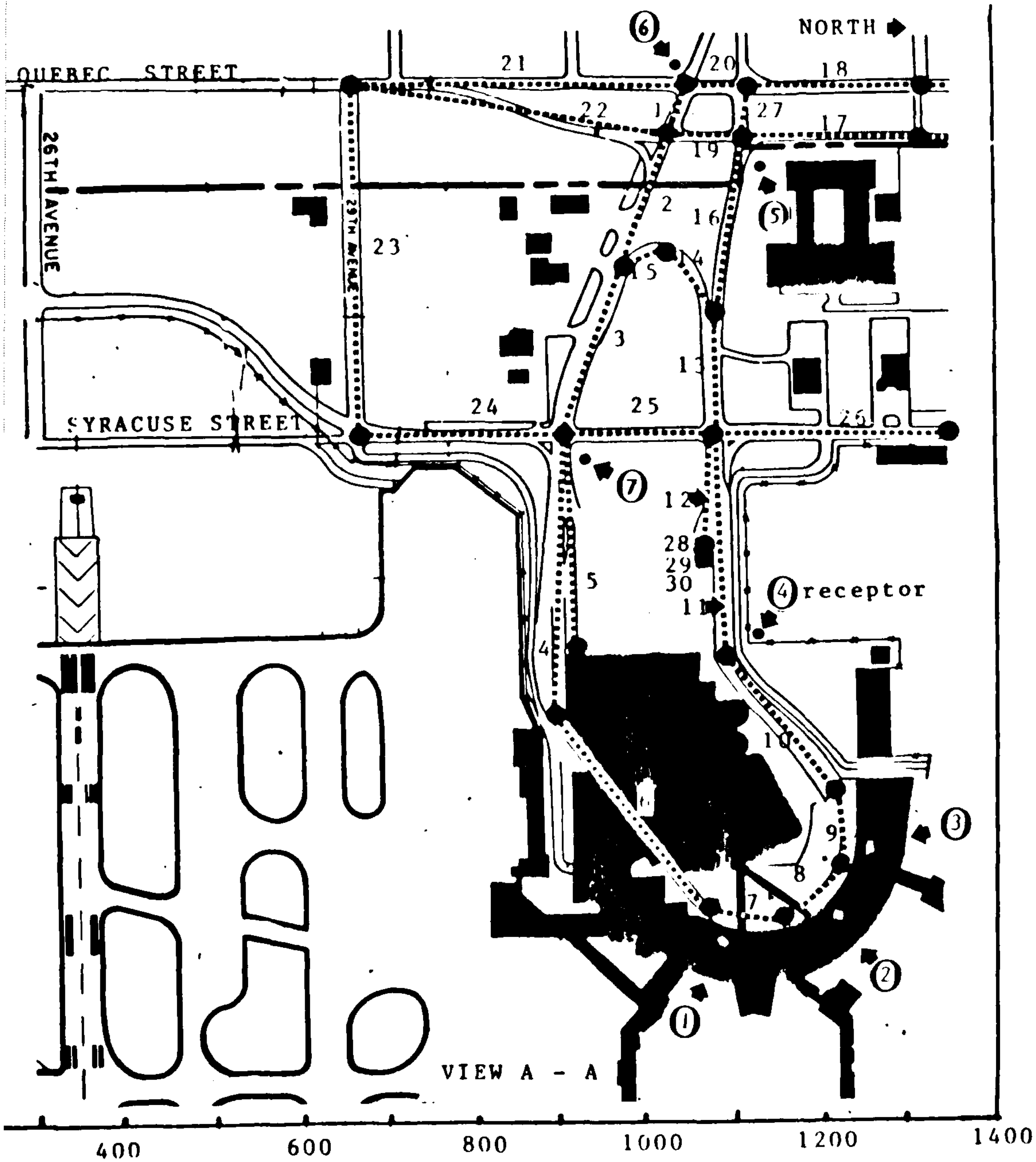


Figure 5

PEAK HOUR DATA

road #	spd. (mph)	veh. per hr.	% cold starts
1	10	1535	10
2	30	1967	10
3	30	2647	10
4	30	2130	10
5	25	1098	10
6	20	2130	10
7	5	2130	10
8	5	2130	10
9	5	2130	10
10	20	2130	10
11	30	2130	20
12	15	1000	50
13	30	2735	30
14	30	680	20
15	30	680	20
16	35	2055	20
17	40	1797	10
18	35	2612	10
19	10	1590	10
20	10	2422	10
21	40	2219	10
22	35	1345	10
23	30	500	10
24	30	1000	10
25	30	100	10
26	30	495	20
27	10	1895	20
28	0	3-Q	60
29	0	3-Q	60
30	0	3-Q	60

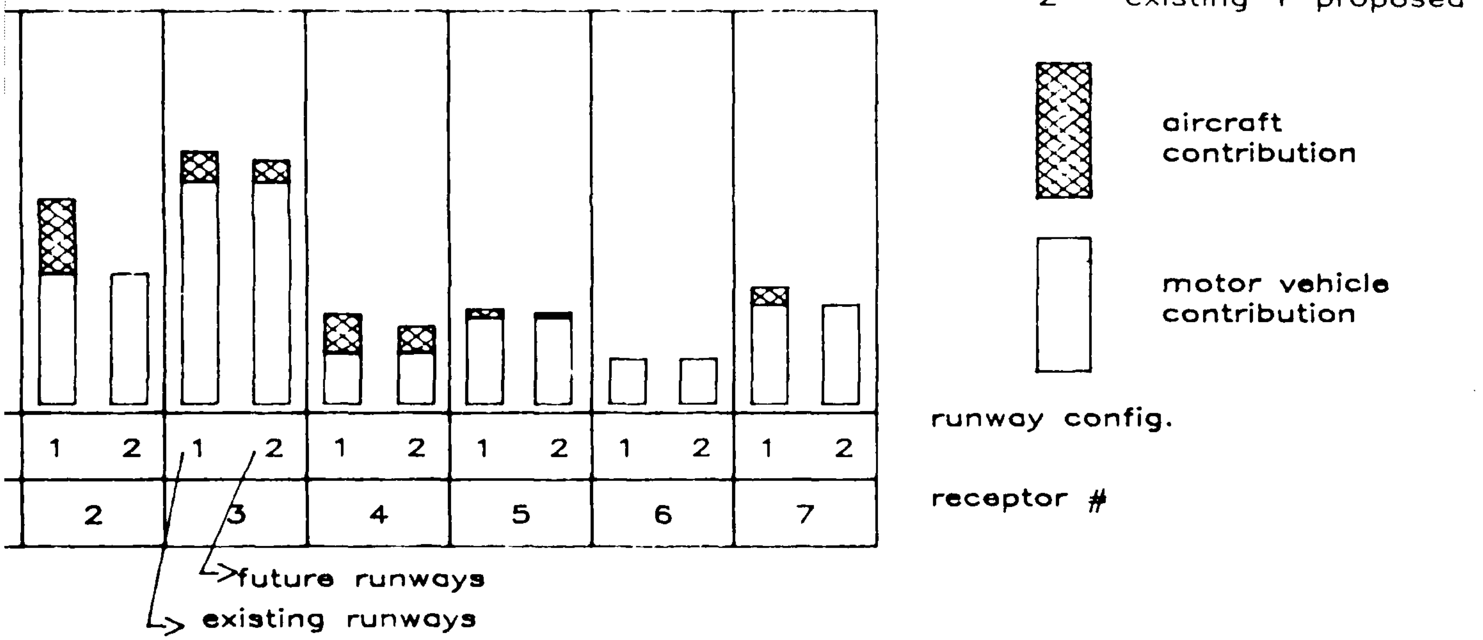
N OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
8 HOUR AVERAGE CONCENTRATIONS
(December 9, 1982 meterology)

noxide
on
average

METEROLOGICAL CONDITIONS

Date — Dec 9,1982
hours— 1700 thru 2400

RUNWAY CONFIGURATION
1 — existing
2 — existing + proposed



SOURCE INFORMATION
Peak hour activity assumed for all
hours of the day modeled

Figure 6

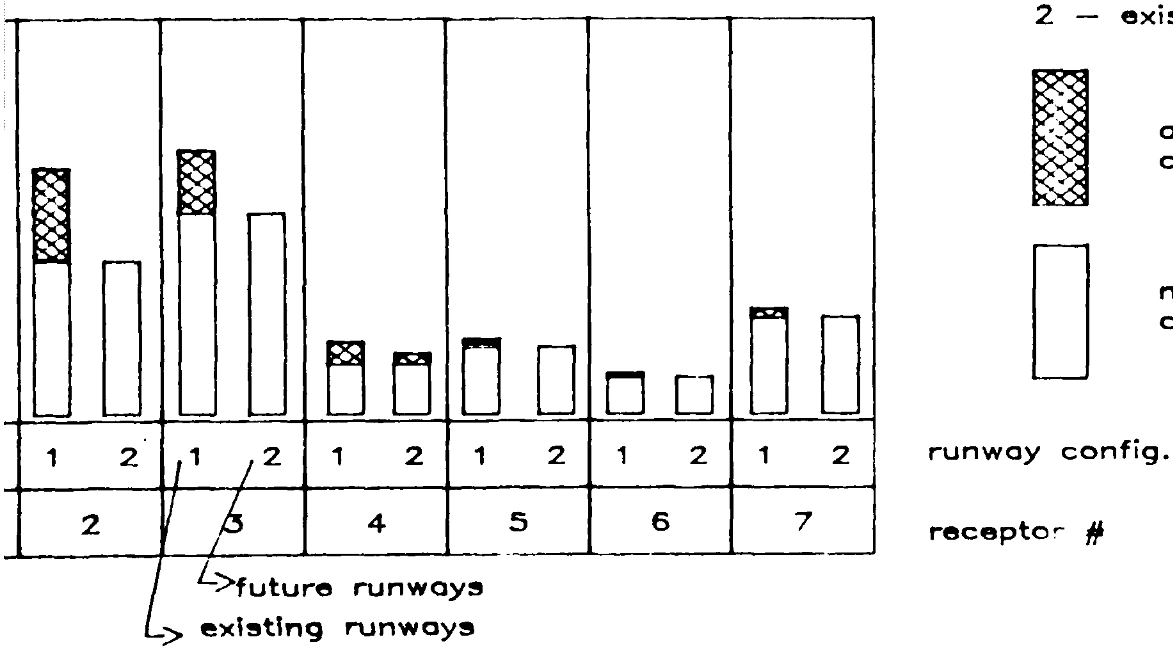
N OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
8 HOUR AVERAGE CONCENTRATIONS
(December 16, 1982 meterology)

noxide
on
average

METEROLOGICAL CONDITIONS

Date — Dec 16,1982
hours— 1600 thru 2300

RUNWAY CONFIGURATION
1 — existing
2 — existing + proposed



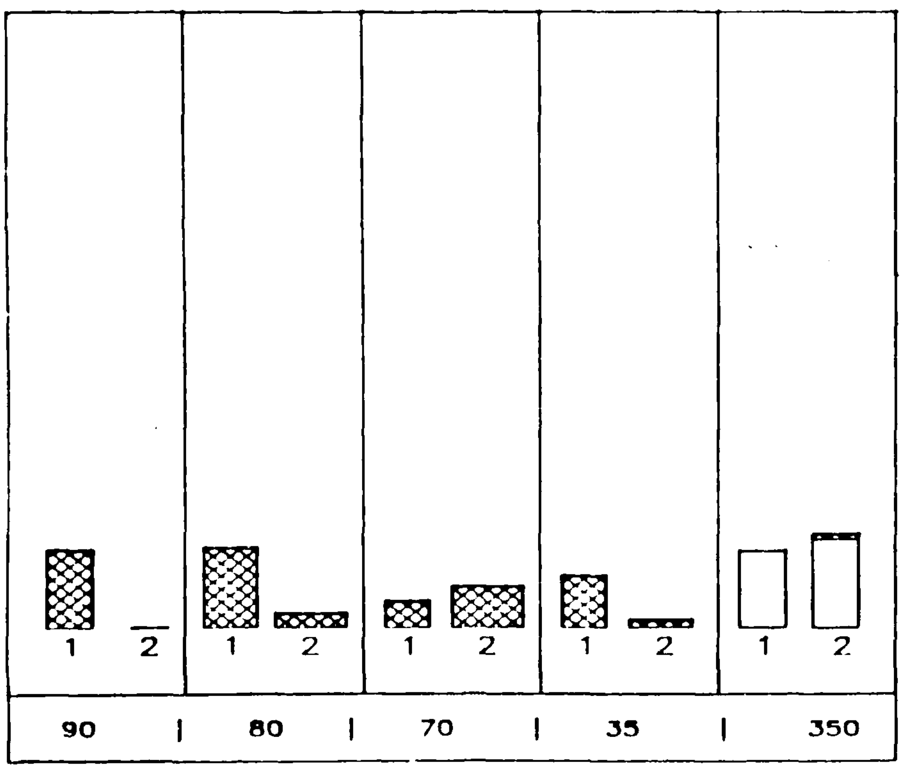
SOURCE INFORMATION
Peak hour activity assumed for all
hours of the day modeled

Figure 7

TION OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO — NORTH DEPARTURE — RECEPTOR # 1

ENT. *
/m~3)
on
oxide)

wind speed ------- 1 meter/sec.
stability (P/G) ------- D
outside air temperature 0 F.



aircraft contribution

motor vehicle contribution

1—receptor concentrations (existing runway scenario)

2—receptor concentrations (additional runway scenario)

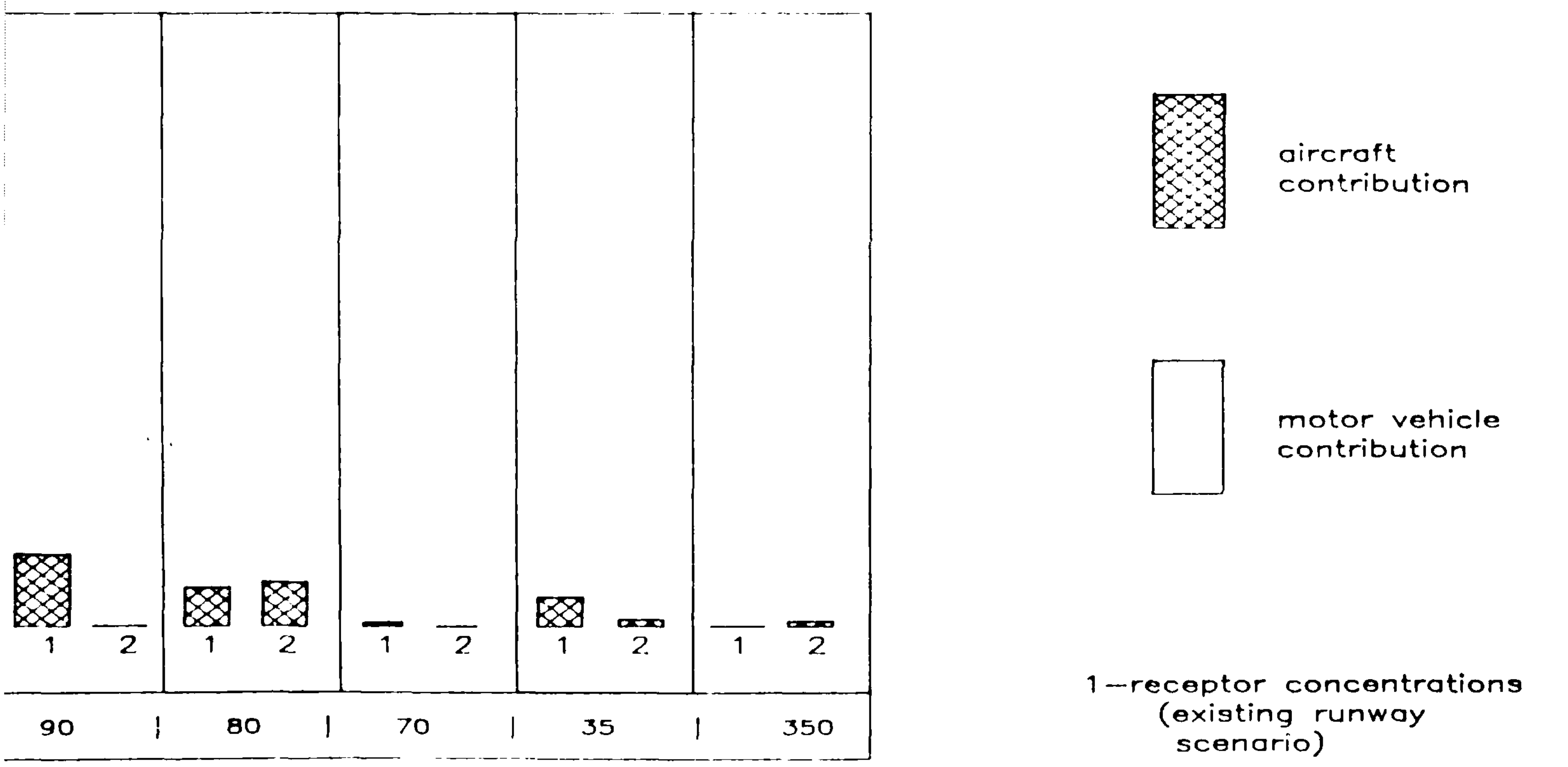
ONE HOUR AVERAGE

Figure 8

ON OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO -- NORTH DEPARTURE — RECEPTOR # 2

-3)

de)

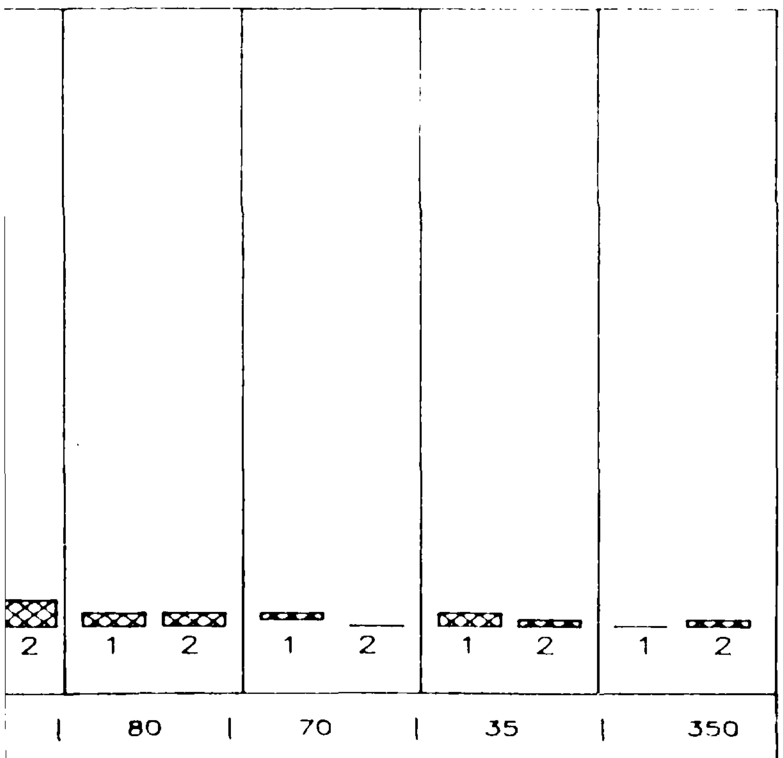


NE HOUR AVERAGE

Figure 9

MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO -- NORTH DEPARTURE -- RECEPTOR # 3

wind speed ------- 1 meter/sec.
stability (P/G) ------- D
outside air temperature 0 F.



aircraft contribution

motor vehicle contribution

1—receptor concentrations (existing runway scenario)

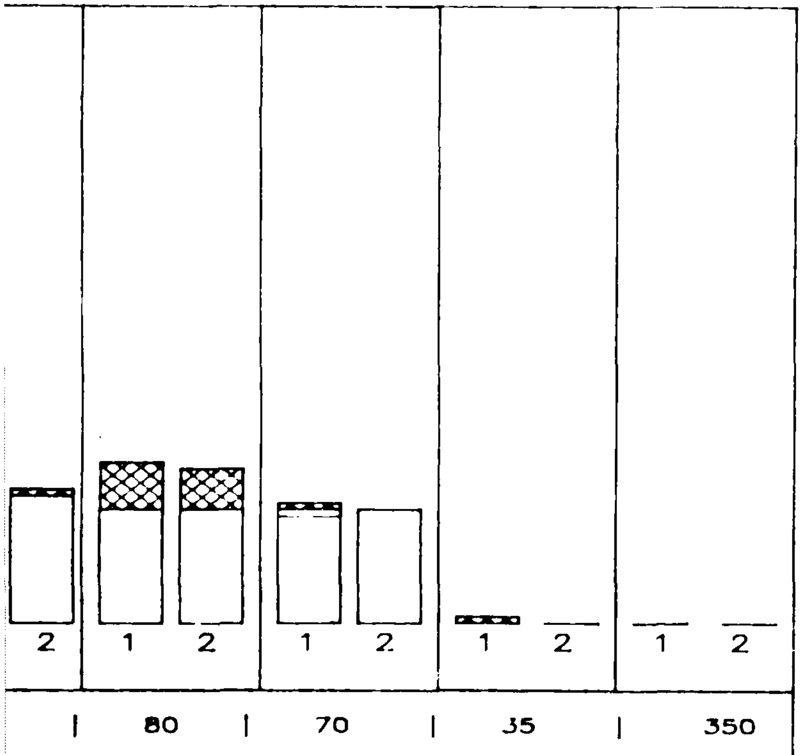
2—receptor concentrations (additional runway scenario)

)UR AVERAGE

Figure 10

F MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO – NORTH DEPARTURE – RECEPTOR # 4

wind speed ------- 1 meter/sec.
stability (P/G) ------- D
outside air temperature 0 F.



aircraft contribution

motor vehicle contribution

1–receptor concentrations (existing runway scenario)

2–receptor concentrations (additional runway scenario)

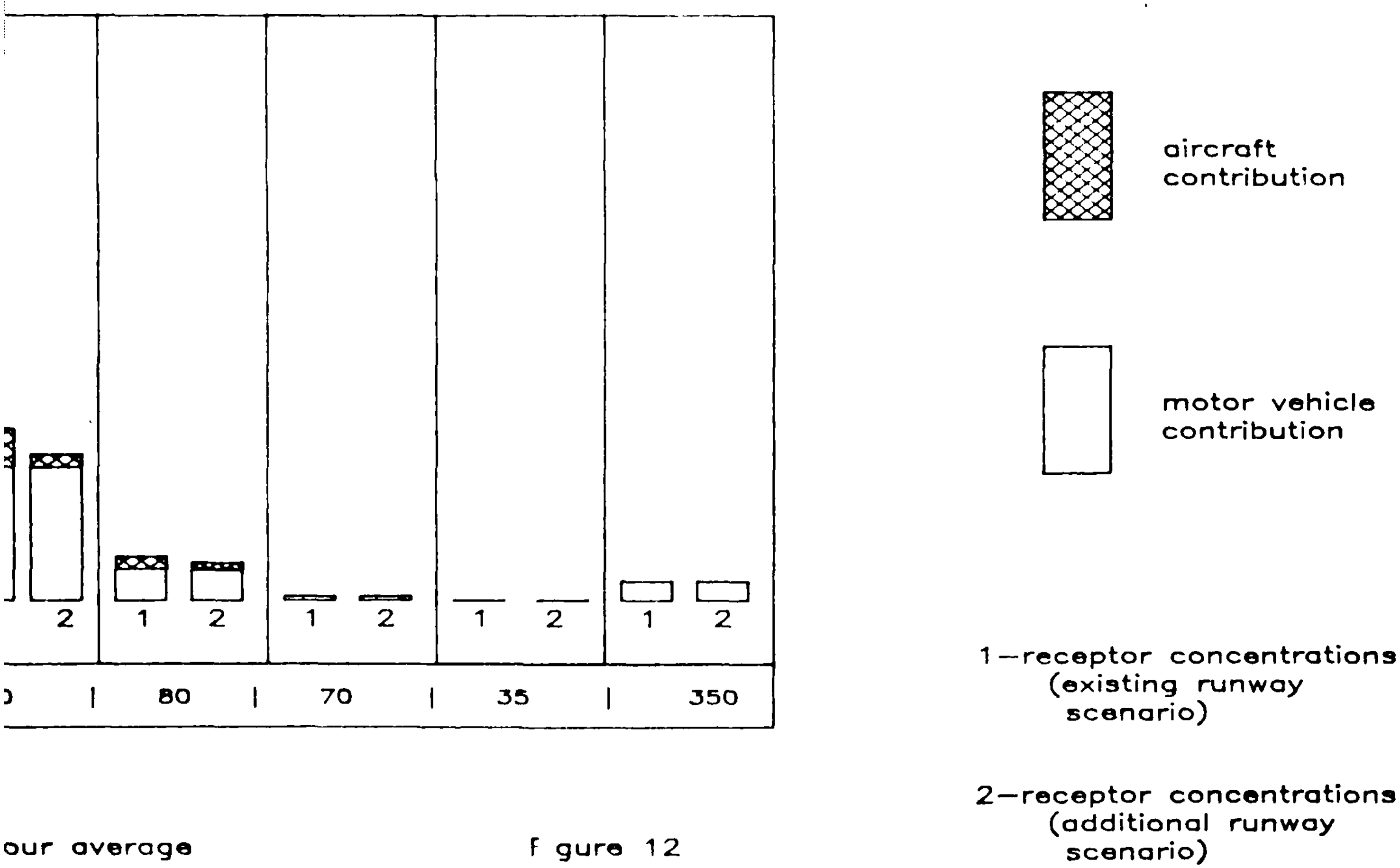
average

Figure 11

E-20

OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO — NORTH DEPARTURE — RECEPTOR # 5

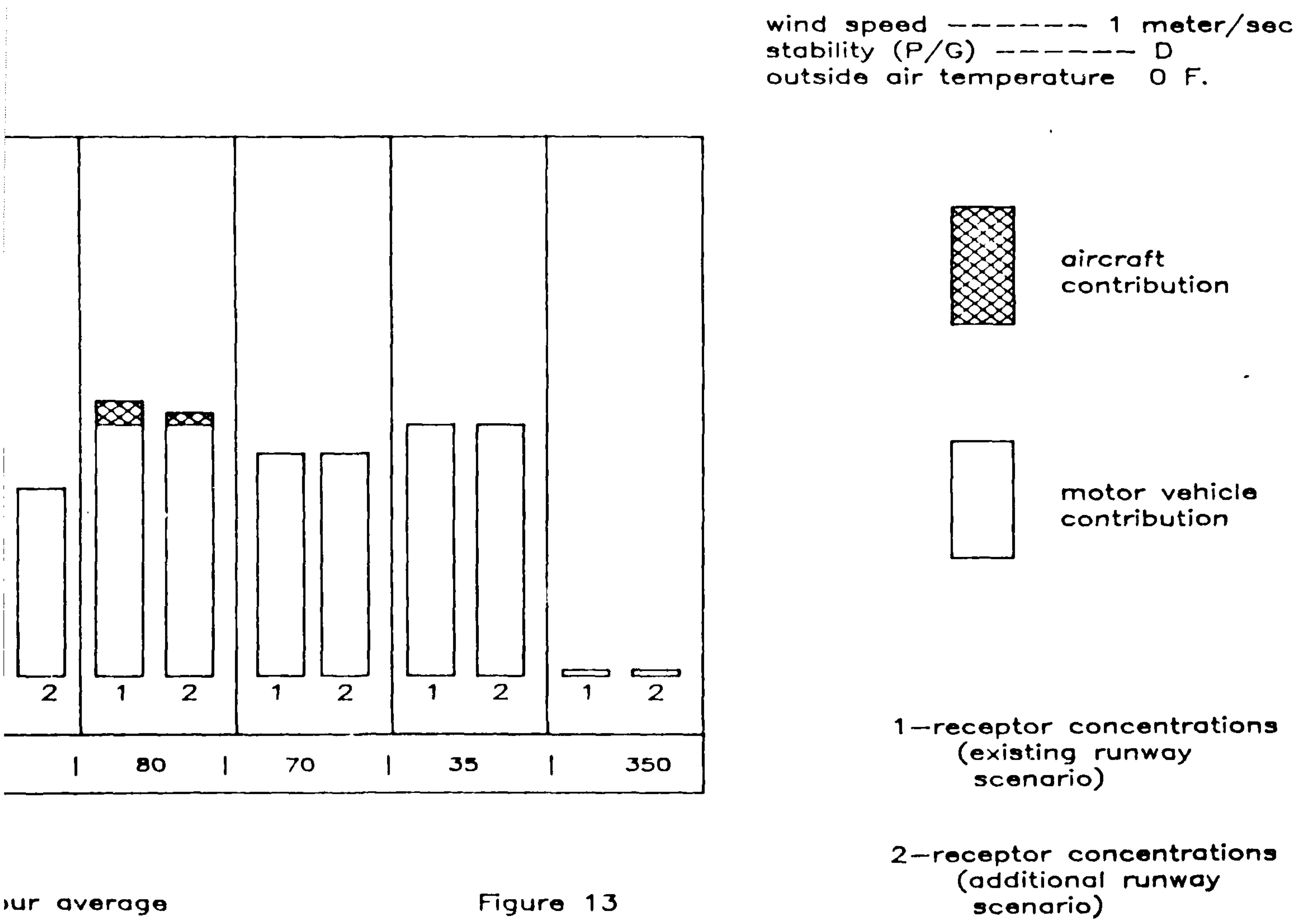
wind speed ------- 1 meter/sec.
stability (P/G) ------- D
outside air temperature 0 F.



our average

f gure 12

)F MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO — NORTH DEPARTURE — RECEPTOR # 6

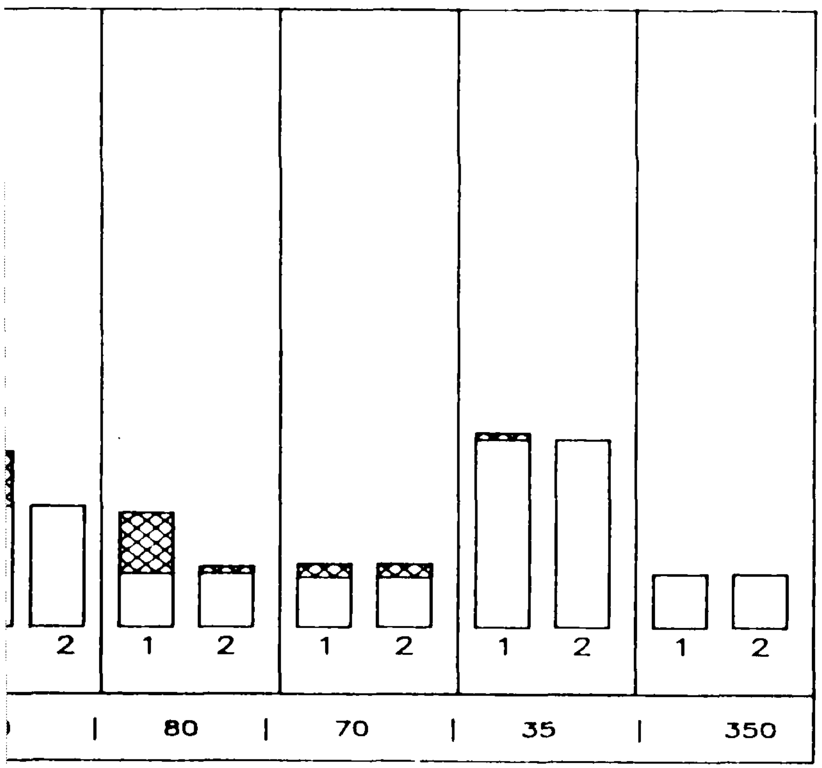


)ur average

Figure 13

OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO — NORTH DEPARTURE — RECEPTOR # 7

wind speed ------- 1 meter/sec.
stability (P/G) ------- D
outside air temperature 0 F.



aircraft contribution

motor vehicle contribution

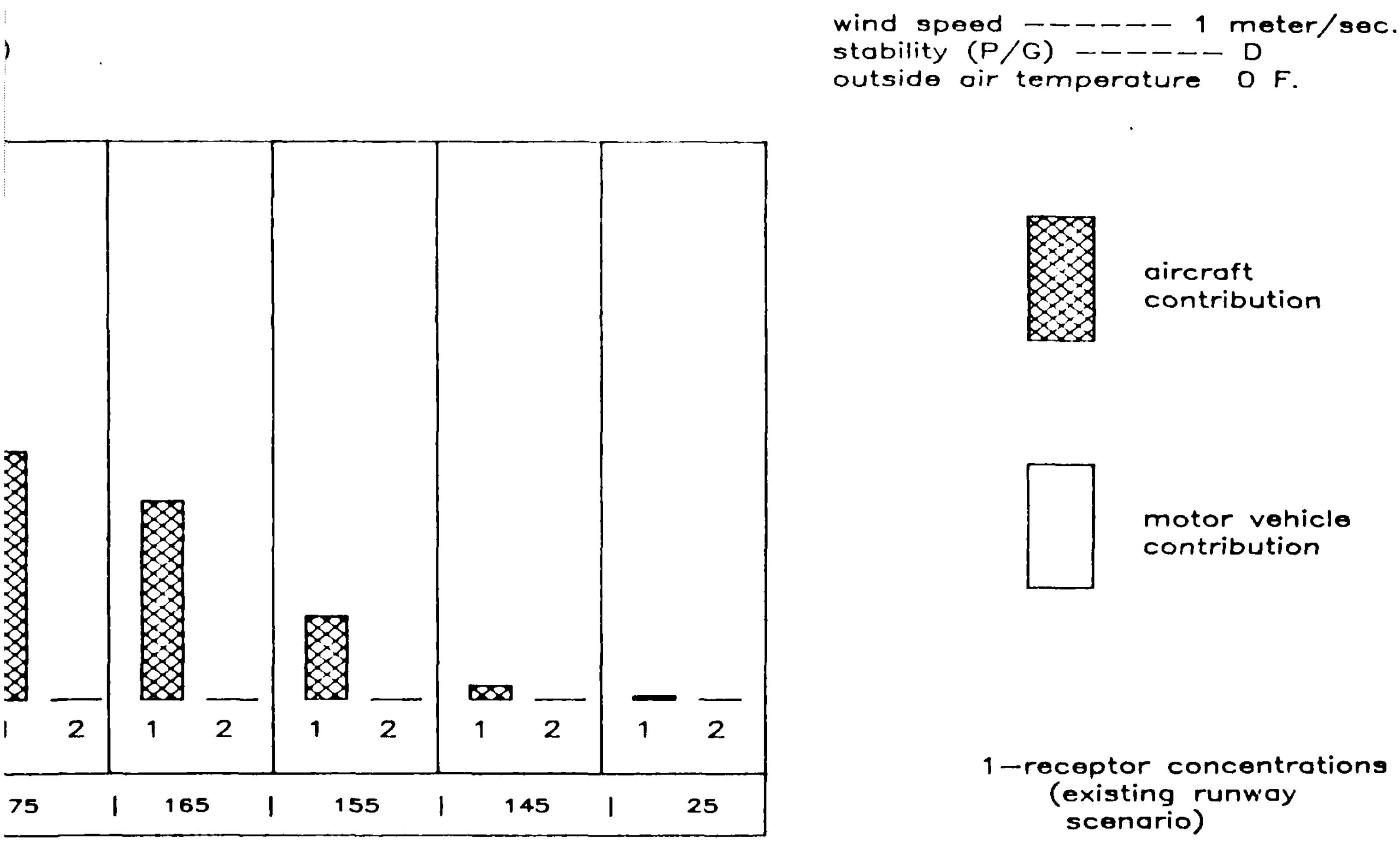
1—receptor concentrations (existing runway scenario)

2—receptor concentrations (additional runway scenario)

our average

Figure 14

OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO — EAST DEPARTURE — RECEPTOR # 1



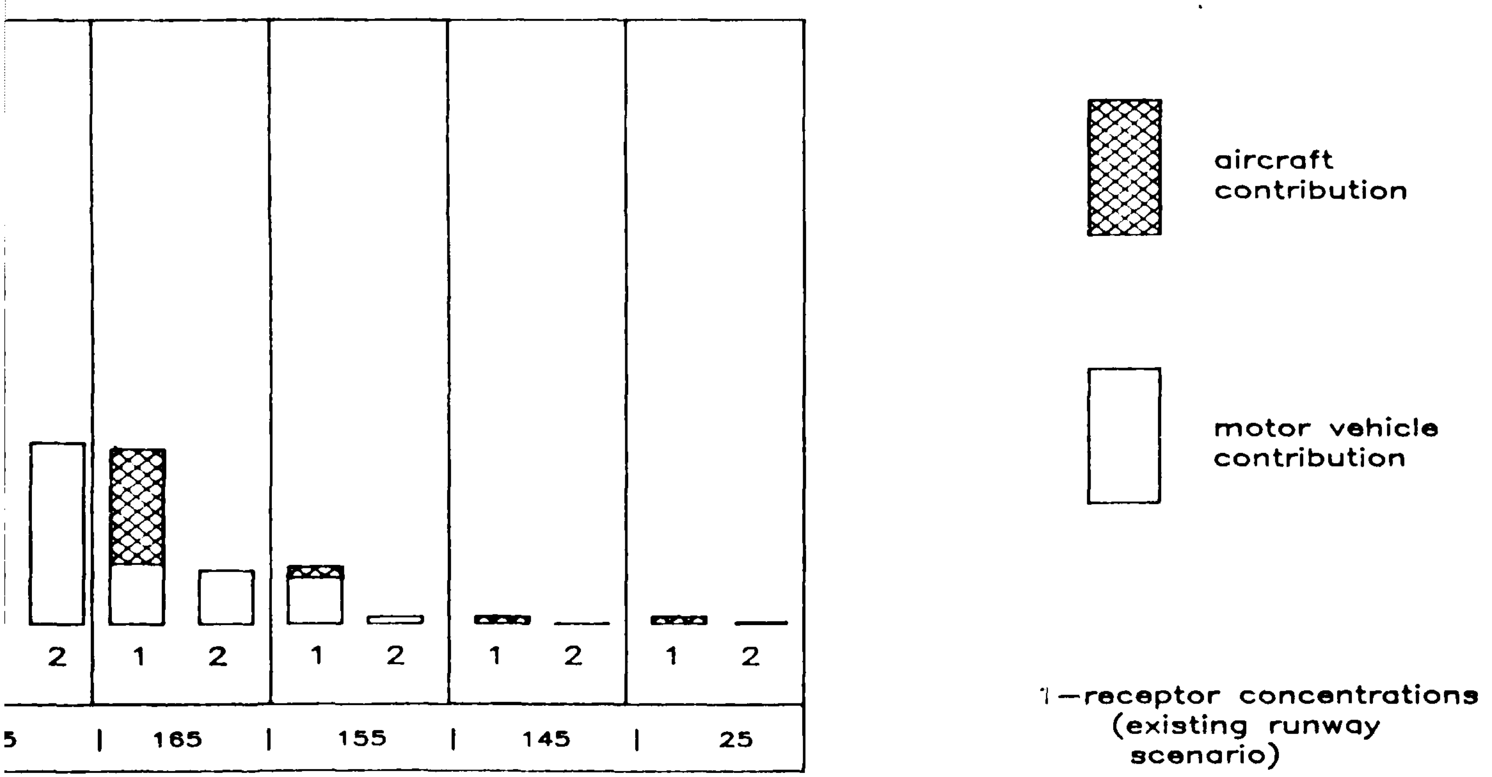
2—receptor concentrations (additional runway scenario)

hour average

Figure 15

)F MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO — EAST DEPARTURE — RECEPTOR # 2

wind speed ——————— 1 meter/sec.
stability (P/G) —————— D
outside air temperature 0 F.



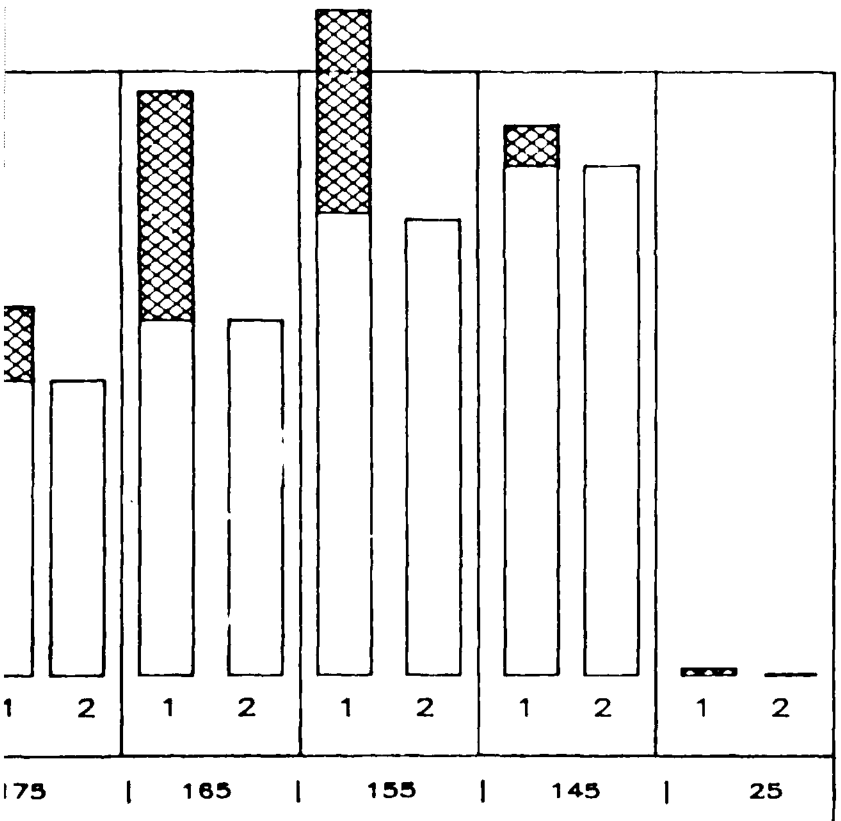
2—receptor concentrations (additional runway scenario)

)ur average

FIGURE 16

OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO – EAST DEPARTURE – RECEPTOR # 3

wind speed ------- 1 meter/sec.
stability (P/G) ------- D
outside air temperature 0 F.



aircraft contribution

motor vehicle contribution

1—receptor concentrations (existing runway scenario)

2—receptor concentrations (additional runway scenario)

hour average

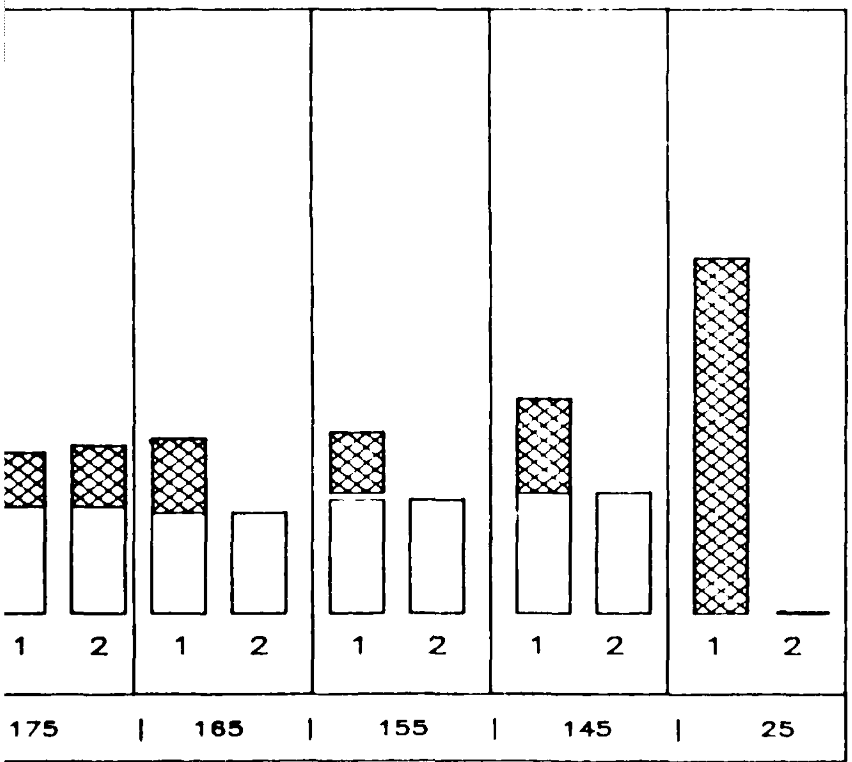
Figure 17

I OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO — EAST DEPARTURE — RECEPTOR # 4

5)

)

wind speed ------- 1 meter/sec.
stability (P/G) ------- D
outside air temperature 0 F.



aircraft contribution

motor vehicle contribution

1—receptor concentrations (existing runway scenario)

2—receptor concentrations (additional runway scenario)

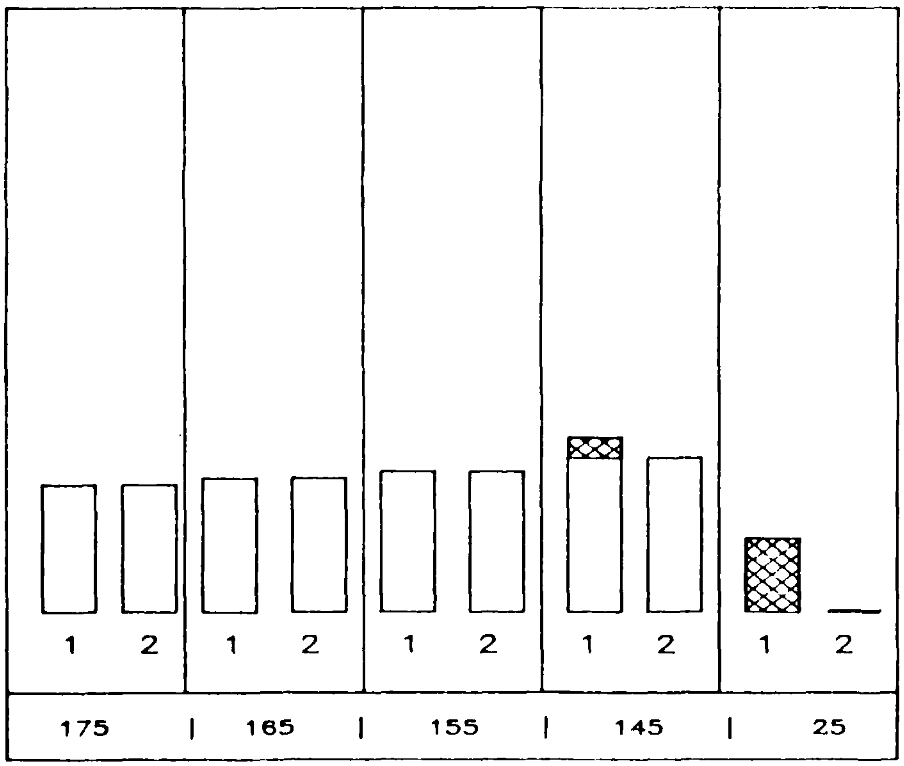
hour average

FIGURE 18

UTION OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO — EAST DEPARTURE — RECEPTOR # 5

:ent.*
/m~3)
bon
oxide)

wind speed ------- 1 meter/sec.
stability (P/G) ------- D
outside air temperature 0 F.



aircraft contribution

motor vehicle contribution

1—receptor concentrations (existing runway scenario)

2—receptor concentrations (additional runway scenario)

one hour average

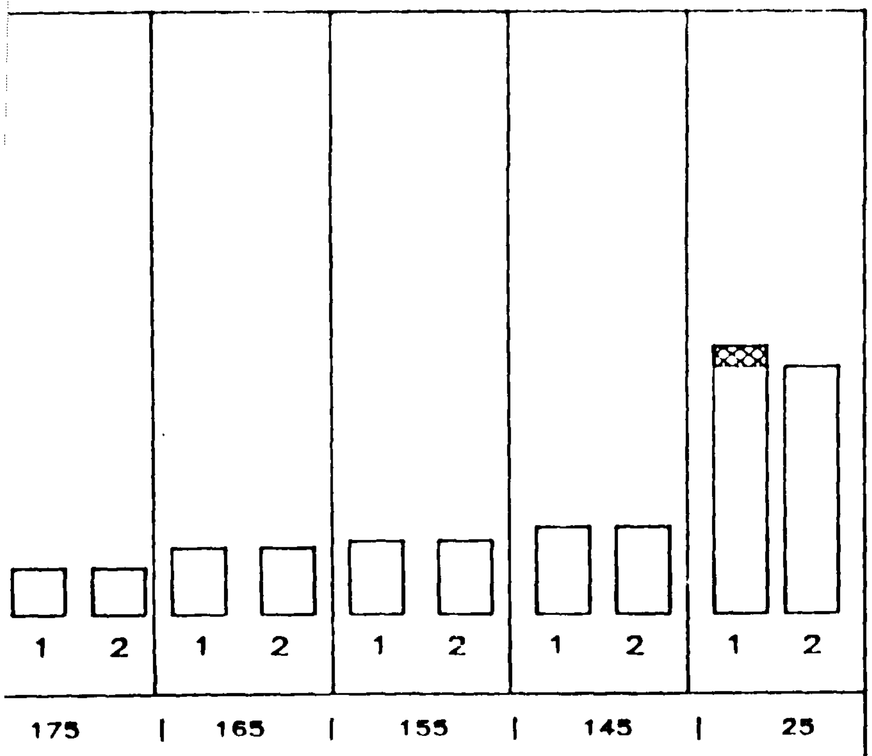
FIGURE 19

N OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO — EAST DEPARTURE — RECEPTOR # 6

3)

e)

wind speed ------- 1 meter/sec.
stability (P/G) ------- D
outside air temperature 0 F.



aircraft contribution

motor vehicle contribution

1—receptor concentrations (existing runway scenario)

2—receptor concentrations (additional runway scenario)

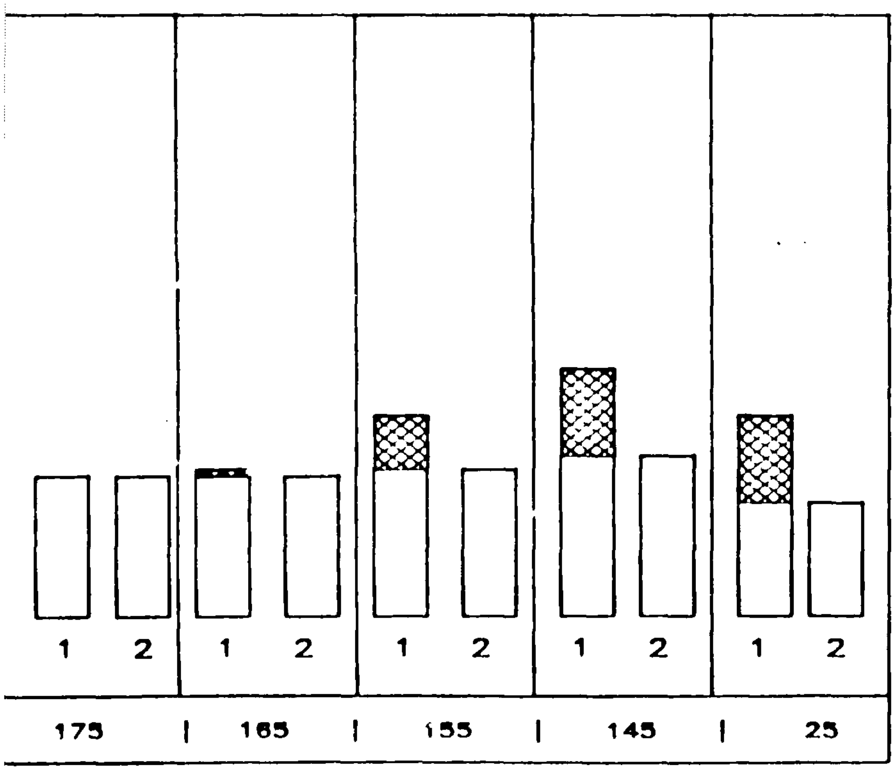
e hour average

FIGURE 20

ON OF MOTOR VEHICLES AND AIRCRAFT TO POLLUTION AT STAPLETON INTERNATIONAL AIRPORT
WORST CASE SCENARIO — EAST DEPARTURE — RECEPTOR # 7

t.*
)~3)
n
ide)

wind speed ——————— 1 meter/sec.
stability (P/G) ——————— D
outside air temperature 0 F.



aircraft contribution

motor vehicle contribution

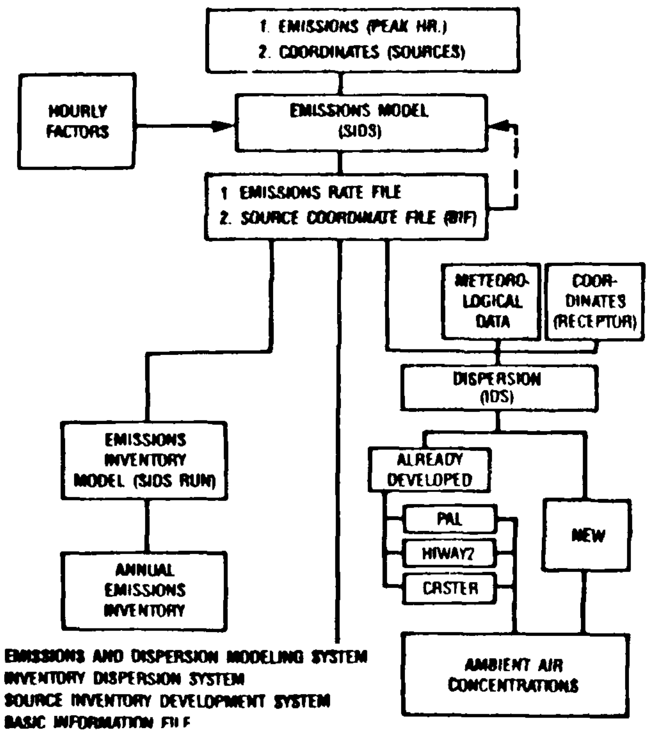
1—receptor concentrations (existing runway scenario)

2—receptor concentrations (additional runway scenario)

ne hour average

FIGURE 21

GRAPHICAL INPUT MICROCOMPUTER MODEL (GIMM) FLOW DIAGRAM



EDMS — EMISSIONS AND DISPERSION MODELING SYSTEM
IDS — INVENTORY DISPERSION SYSTEM
SIDS — SOURCE INVENTORY DEVELOPMENT SYSTEM
BIF — BASIC INFORMATION FILE

Figure 22

COMPARISON BETWEEN GIMM AND EPA MODELS*

Mg/M^3

Automobile Sources

Receptor #	1	2	3	4	5	6	7
GIMM	0	.5	34.5	8.2	10.5	5.6	11.0
HIWAY2	0	.5	33.4	7.8	9.9	5.6	10.3

Aircraft Sources

Receptor #	1	2	3	4	5	6	7
GIMM	6.2	3.0	16.4	5.4	.0	.0	4.1
PAL	6.8	2.9	16.0	5.5	.0	.0	4.0

*Highest Concentration Case
East Departure
Wind from 155°
Present Runway Configuration

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4 Environmental Protection Agency, Research Triangle Park, NC, "Compilation of Air Pollutant Emission Factors - Supplement 10," AP-42, February 1980.

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7 Drew, Donald R., McGraw-Hill, "Traffic Flow Theory and Control," Library of Congress Catalog Card Number 68-13626, New York, 1968.

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APPENDIX A

PRINTOUT OF MOTOR VEHICLE POLLUTION
FOR DIFFERENT WIND DIRECTIONS - APPENDAGE
TO REPORT FAA-EE-86-7 (REF. 1)

This appendix is a printout of the motor vehicle pollution for roadways at Stapleton International Airport. It repeats the printout of wind directions 240 degrees and 270 degrees in Ref. 1 and adds the printouts for wind directions of 180, 200, 225, and 330 degrees. The date header on each printout represents the day that the run was made.

TYPICAL PRINTOUT (THERE ARE 6 PRINTOUTS IN THE COMPLETE APPENDIX WHICH IS INCLUDED IN REPORT FAA-EE-86-11

NOV- 7-86 (1600 HR.)

INPUTS														OUTPUTS				
COORDINATES OF SOURCES (M) ORIGIN AT (0 , 0)					INITIAL PARAMETERS(M)			(MOBILE 3)						EMISSION RATES GM/SEC				
ROAD #	X1	Y1	X2	Y2	SIG Z	SIG Y	PLUME HT.	CARS/HR	MPH	%COLD START	TEMP (F)	YEAR		CO	HC	NOX	SOX	PART
1	46,	397	398,	263	1.5	3	1	1000	30	0	10	0	1986	4.81E00	4.45E-1	2.49E-1	5.57E-4	2.02E-2
2	398,	264	844,	263	1.5	3	1	1300	30	0	10	0	1986	7.40E00	6.86E-1	3.83E-1	9.01E-4	3.11E-2
3	842,	261	1057,	424	1.5	3	1	1300	20	0	10	0	1986	6.59E00	5.58E-1	2.06E-1	5.45E-4	1.85E-2
4	1056,	422	1102,	501	1.5	3	1	1300	5	0	10	0	1986	6.43E00	4.90E-1	7.60E-2	1.85E-4	6.37E-3
5	1099,	501	1069,	590	1.5	3	1	1300	5	0	10	0	1986	6.61E00	5.04E-1	7.81E-2	1.90E-4	6.56E-3
6	1071,	591	1005,	622	1.5	3	1	1300	5	0	10	0	1986	5.13E00	3.91E-1	6.06E-2	1.47E-4	5.07E-3
7	1005,	622	935,	594	1.5	3	1	1300	5	0	10	0	1986	5.11E00	3.89E-1	6.04E-2	1.44E-4	5.07E-3
8	936,	594	718,	460	1.5	3	1	1300	20	0	10	0	1986	6.28E00	5.33E-1	1.97E-1	5.20E-4	1.80E-2
9	718,	460	436,	450	1.5	3	1	1300	30	0	10	0	1986	4.68E00	4.34E-1	2.42E-1	5.71E-4	1.97E-2
10	422,	459	343,	445	1.5	3	1	1000	30	0	10	0	1986	1.15E00	1.07E-1	5.95E-2	1.40E-4	4.85E-3
11	343,	444	51,	474	1.5	3	1	1000	35	0	10	0	1986	3.25E00	3.13E-1	2.00E-1	4.57E-4	1.55E-2
12	53,	873	47,	0	1.5	3	1	3400	35	0	10	0	1986	3.28E01	3.16E00	2.02E00	4.60E-3	1.60E-1
13	453,	874	460,	0	1.5	3	1	100	30	0	10	0	1986	1.12E00	1.03E-1	5.77E-2	1.36E-4	4.69E-3
14	431,	458	350,	364	1.5	3	1	300	30	0	10	0	1986	4.75E-1	4.40E-2	2.46E-2	5.77E-5	2.00E-3
15	351,	363	399,	260	1.5	3	1	300	30	0	10	0	1986	4.35E-1	4.03E-2	2.25E-2	5.33E-5	1.84E-3
16	600,	460	635,	460	1.5	3	1	QUEUE	0	0	10	0	1986	3.23E00	2.43E-1	3.77E-2	8.75E-5	3.03E-3
													TOTAL	9.55E01	8.44E00	3.98E00	9.32E-3	3.23E-1

DISPERSION REPORT

INPUTS								OUTPUT				
DATE	HR	U (M/S)	WD (DEG)	P/G (A=1)	RECEPTOR NO.	X	Y	CONCENTRATION GM/M^3 CO	HC	NOX	SOX	PART
NOV- 7-86	16	1	240	4	1	1114	458	1.14E-2	8.90E-4	1.29E-4	4.64E-7	1.60E-5
NOV- 7-86	16	1	240	4	2	1102	563	2.00E-2	1.54E-3	2.82E-4	6.79E-7	2.35E-5
NOV- 7-86	16	1	240	4	3	1046	629	2.77E-2	2.16E-3	4.41E-4	1.05E-6	3.72E-5
NOV- 7-86	16	1	240	4	4	729	490	6.89E-3	6.19E-4	3.15E-4	7.37E-7	2.55E-5
NOV- 7-86	16	1	240	4	5	81	409	1.13E-2	1.07E-3	6.64E-4	1.52E-6	5.27E-5
NOV- 7-86	16	1	240	4	6	477	16	3.68E-4	3.41E-5	1.91E-5	4.49E-8	1.55E-6
NOV- 7-86	16	1	240	4	7	483	285	1.21E-3	1.15E-4	7.03E-5	1.62E-7	5.60E-6

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APPENDIX B

GIMM PRINTOUTS FOR THE STAPLETON
INTERNATIONAL AIRPORT SCENARIO

Figures 6 through 21 were prepared from the printouts listed in this Appendix. These data include the following combinations of information:

1. 8-hour and 1-hour analysis
2. motor vehicles and airplanes
3. existing and future runways
4. north and east departures

The interrelationship of these combinations is shown in Figure B-1.

To facilitate Graphics Tablet use, the wind direction values listed in the printouts had to be referenced from the top of the page. This required rotating the maps of Figures 1 - 5 from a vertical north orientation. The user of Appendix B data must therefore subtract 90 degrees from all listed wind angles to establish the true wind angle.

The graphics tablet relates all coordinates to a (0,0) map origin. Since the origin of the large scale map (Figure 1) is (0,0), and aircraft coordinates are entered from this map, these sources do not have to be corrected. However, the coordinate printouts for motor vehicles have to be corrected because they are entered into the Graphics Tablet from the

COMPUTER PRINTOUT SUMMARY

8 Hour Analyses

MOTOR VEHICLES	AIRPLANES	
Existing and Future Runways	Existing Runways	Future Runways
East Departure Run #5	Run #1	
		Run #2
North Departure Run #5	Run #3	
		Run #4

1 Hour Worst Cast Analsyis

MOTOR VEHICLES	AIRPLANES	
Existing and Future Runways	Existing Runways	Future Runways
East Departure Run #10	Run #6	
		Run #7
North Departure Run #10	Run #8	
		Run #9

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RUN# 1

TYPICAL PRINTOUT (THERE ARE OVER 100 OF THEM IN THE COMPLETE APPENDIX)

EMISSION REPORT

DEC- 9-86 (1700 HR.)

INPUTS											OUTPUTS				
COORDINATES OF SOURCES (M): ORIGIN AT (0,0)					INITIAL PARAMETERS(M)				(AP-42)		EMISSION RATES				
											GM/SEC				
REC #	X1	Y1	X2	Y2	SIG Y	PLUME HT.	SIG Z	ACFT/HR	AIRCRAFT TYPE		CO	HC	NOX	SOX	PART
1	612	2827	612	750	16	15	10	14	B737-200/JT8D-17		2.08E-1	2.06E-2	8.94E00	4.11E-1	1.54E-1
1	740	3030	612	2827	16	15	10	14	B737-200/JT8D-17		3.45E01	8.91E00	3.44E00	1.01E00	3.11E-1
2	612	2827	612	750	16	15	10	4	DH6/PT6A-27		3.61E-3	0.00E00	2.08E00	3.52E-3	0.00E00
2	740	3030	612	2827	16	15	10	4	DH6/PT6A-27		1.06E00	1.46E00	7.06E-2	2.78E-2	0.00E00
3	612	2827	612	750	16	15	10	2	CV580/501D22A		2.04E-2	2.01E-3	8.06E-2	1.00E-2	0.00E00
3	740	3030	612	2827	16	15	10	2	CV580/501D22A		3.35E00	1.35E00	2.71E-1	7.78E-2	0.00E00
4	612	2827	612	750	16	15	10	1	B99/PT6A-27		9.03E-4	0.00E00	6.99E-1	8.08E-4	0.00E00
4	740	3030	612	2827	16	15	10	1	B99/PT6A-27		4.64E-1	3.64E-1	1.76E-2	6.94E-3	0.00E00
5	612	2827	612	750	16	15	10	19	NAVAJO/TIO-540		8.96E00	7.71E-2	2.27E-3	1.06E-3	0.00E00
5	740	3030	612	2827	16	15	10	19	NAVAJO/TIO-540		3.08E01	2.04E00	1.17E-2	1.32E-2	0.00E00
6	338	3306	337	313	16	15	10	3	B747-200B/JT9D-70		6.04E-2	5.13E-2	1.06E01	3.42E-1	6.61E-2
6	453	2605	338	3306	16	15	10	3	B747-200B/JT9D-70		2.31E01	4.58E-1	1.00E00	6.03E-1	8.33E-1
7	338	3306	337	313	16	15	10	1	DC-10-30/CF6-50C		1.67E-3	8.36E-4	2.96E00	8.33E-2	2.33E-3
7	453	2605	338	3306	16	15	10	1	DC-10-30/CF6-50C		8.32E00	3.42E00	2.05E-1	1.15E-1	4.17E-3
8	338	3306	337	313	16	15	10	1	B767/CF6-80A		5.08E-2	1.45E-2	1.49E00	5.08E-2	0.00E00
8	453	2605	338	3306	16	15	10	1	B767/CF6-80A		2.11E00	4.71E-1	2.54E-1	7.50E-2	0.00E00
9	338	3306	337	313	16	15	10	19	B727-200*/JT8D-17		5.86E-1	4.19E-2	1.70E01	8.37E-1	3.14E-1
9	453	2605	338	3306	16	15	10	19	B727-200*/JT8D-17		7.02E01	1.01E01	7.01E00	2.06E00	6.33E-1
10	338	3306	337	313	16	15	10	17	B737-200/JT8D-17		3.49E-1	2.50E-2	1.01E01	4.99E-1	1.07E-1
10	453	2605	338	3306	16	15	10	17	B737-200/JT8D-17		4.19E01	1.08E01	4.18E00	1.23E00	3.78E-1
										TOTAL	2.35E02	4.76E01	7.14E01	7.54E00	2.08E00

DISPERSION REPORT

INPUTS								OUTPUT				
DATE	HR	W/S M/S	WD DEG	P/G (A=1)	RECEPTOR			CONCENTRATION GM/M^3				
					NO.	X	Y	CO	HC	NOX	SOX	PART
DEC- 9-86	17	2.6	230	4	1	1070	2990	1.37E-4	0.77E-6	2.00E-4	1.19E-5	4.07E-6
DEC- 9-86	17	2.6	230	4	2	1197	3009	8.19E-5	1.76E-6	2.27E-4	9.18E-6	3.03E-6
DEC- 9-86	17	2.6	230	4	3	1241	3085	1.00E-4	5.31E-6	2.31E-4	9.64E-6	3.27E-6
DEC- 9-86	17	2.6	230	4	4	1114	3335	8.77E-3	1.67E-3	7.44E-4	1.65E-4	5.38E-5
DEC- 9-86	17	2.6	230	4	5	1126	3877	1.75E-3	3.98E-4	6.41E-4	7.03E-5	2.05E-5
DEC- 9-86	17	2.6	230	4	6	1011	4013	9.86E-5	2.23E-5	8.16E-5	5.89E-6	2.21E-6
DEC- 9-86	17	2.6	230	4	7	923	2545	2.41E-3	5.49E-4	5.46E-4	8.25E-5	3.48E-5

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APPENDIX C

AIRCRAFT CAPACITY/DEMAND ANALYSIS

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1. Introduction

The aircraft pollution burden is determined by modeling aircraft queuing emissions. A capacity/demand analysis is required to estimate this burden. The demand portion of this analysis is described in section 3.3.1 of the main report. The capacity analysis is made by selecting north-south and east-west runway configurations from Reference 6 that were determined to be "worst case" with respect to air quality and therefore appropriate for air quality analysis.

2. Runway Usage Selection for Air Quality Analysis

Departures to the east or to the north were selected as the appropriate runway geometries to use in this air quality analysis. These two geometries, which were part of the seven geometries listed in Reference 6, were selected because they place aircraft emissions closest to the pollution receptors at the terminal and, therefore, would record the highest possible pollution values.

For each of the runway geometries listed above, two capacity values are listed in Reference 6; one during flight under Visual Flight Rules (VFR), and the other during flight under Instrument Flight Rules (IFR). The values listed under VFR were selected for this analysis because they predominate under the "worst case" meteorological conditions provided by the CDPH.

3. Delay calculations

As was mentioned in the main text of this report (section 3.3.1), 81 aircraft were estimated to depart from the airport during the peak hour. For the existing configuration, these aircraft are assumed to depart on two parallel runways either to the east or to the north. Departures would therefore consist of 40 airplanes on one runway and 41 on the other.

During the peak hour there would be pressure to disperse these aircraft to the third proposed runway. Assuming an even split over the three runways, the departure rates would be 27 aircraft per hour on each runway.

The total VFR capacity from Reference 6 is 150 aircraft per hour. Assuming the takeoff portion of this capacity is 88 aircraft per hour or slightly greater than one half, the following equation from Reference 7 can be used to calculate delays prior to takeoff:

$$T = \frac{q\,(60\text{ min.})}{Q(Q-q)}$$

q = demand (airc./hr)
Q = capacity (airc/hr)
T = queue time (min.)

DELAY CALCULATIONS FOR EXISTING RUNWAY SYSTEM

Assuming a Poisson distribution of aircraft arriving at each of the two takeoff queue areas:

$$T = \frac{40\ (60\ \text{min.})}{44\ (44-40)} = 14\ \text{min/AIRC.} \quad (\text{runway } 1)$$

$$T = \frac{41\ (60\ \text{min.})}{44\ (44-41)} = 19\ \text{min./AIRC.} \quad (\text{runway } 2)$$

For conservatism a 15 minute queue time was selected. With a departure rate of 1 1/2 airplanes per minute the peak queue length would be 10 airplanes. This value is consistant with queue lengths reported by tower personnel during peak hours. It is now possible to use this takeoff capacity estimate to calculate the decrease in queue time with the additional runways.

DELAY CALCULATIONS FOR EXISTING + PROPOSED RUNWAYS

Assume that the proposed east-west or north-south runways are in place and that during peak hours scheduled departures will be evenly directed to these three runways (27-27-27). Assume that each runway has a takeoff capacity of 44 (1/2 of 88) departures per hour.

Under these conditions:

$$T = \frac{27\ (60\ \text{min.})}{44\ (44-27)} = 2.16\ \text{minutes} \quad (\text{all 3 runways})$$

To be conservative 3 minutes was selected

Therefore, aircraft queues at each runway will be:

PRESENT CONFIGURATION ---- 15 minutes

PROPOSED CONFIGURATION --- 3 minutes